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Essays on Competition in the Freight Railroad Industry

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Essays on Competition in the Freight Railroad Industry

by

Daria Pus

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Dedicated to my family and mentors: your support and guidance made this possible.

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Essays on Competition in the Freight Railroad Industry

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This dissertation addresses open issues in complementary goods mergers and tacit collusion as it relates to the freight railroad industry. It provides a broad overview of the freight railroad industry, its leading players, the rate-setting process, and describes dynamics in the markets of different commodities shipped. The standard literature on tacit collusion concentrates on how it influences the pricing of substitutes. However, collusion is also likely to influence the pricing of complements. For example, in static equilibrium, if two local monopolists were selling complementary products, they would charge a higher price than if both products were offered by a single multiproduct monopolist, reducing both the industry profits and the consumer surplus. However, if firms were able to coordinate, they could reach a Pareto improvement by lowering prices to the monopolist level. Therefore, in the markets where firms sell both substitutes and perfect complements, the welfare effect of coordination is ambiguous. The dissertation analyses this question in the context of the US freight railroad industry. Using rail waybill data, I find evidence that prices are higher on average in markets where the route is served jointly by two or more railroads, and thus inefficiency from the pricing of complements is present. I then estimate a structural model where firms set prices a la Bertrand and conduct merger simulations for the firms that sell complements in many markets. I find that mergers are welfare enhancing. They benefit the consumer and merging parties but hurt outsiders. In the last chapter, I estimate a structural model of competition with conduct parameter defined as a function of multimarket contact. I compare industry welfare to the counterfactual of breaking tacit collusion and full monopoly and find that the former is welfare enhancing. The latter reduces the welfare but the effect if smaller in magnitude.

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Chapter 1

Overview of the U.S. freight railroad industry

1.1 Introduction

Freight railroads play an essential role in the U.S. economy. They allow for a more efficient trade between businesses around the country and abroad. Freight railroads hauled 1,616 million tons of freight valued at almost $600 billion in 2012 (Sprung et al. (2018)). Railroads are an essential player in the nation's freight shipping industry. According to Bureau of Transportation Statistics (2018), in 2012 freight railroads carried 34.6% of freight by ton-mile, slightly behind trucks that hauled 38.2%, and well ahead oil pipelines (17.3%), domestic water transportation (9.6%), and air (0.2%).

Freight railroads haul a wide variety of commodities. They move coal from mines in coal basins to coal-fired power plants around the country, automobiles from car manufacturers to dealerships, grains from grain elevators to mills and food manufacturers, intermodal containers from ports to their final destination. Coal is the largest commodity by tons shipped, in 2003 over 600 million tons were hauled by freight railroads[1]. The second place was split by intermodal (shipments in intermodal containers) and metals and minerals

[1] Surface Transportation Board Carload Waybill Sample, 2003-2014.

with about 170 million tons shipped. In terms of revenues, coal and intermodal shipments both collected close to $8 billion in 2003. This reflects the low value of bulk commodities such as coal and metals and minerals. From 2003 to 2014 the amount of coal shipped decreased slightly, while intermodal shipments grew, pushing coal shipments to the second place by revenue.

Commodities shipped by freight railroads are very heterogeneous, and demand for rail services is closely linked with the demand for the commodity. Therefore, it is crucial to understand the dynamics in the industry of the shipper to be able to conduct a proper economic analysis of the freight railroad industry. The main goal of this chapter is to provide a broad overview of the U.S. freight railroad industry, its leading players, and dynamics in shipments of different commodities.

The remainder of this chapter is structured as follows. In section 2 I describe the classification of freight railroads, provide statistics for the largest companies, and show the structure of their networks. In section 3 I dive deep into the different commodities shipped, describe main geographic markets, most popular products hauled, discuss rate and quantity trends over time. Section 4 concentrates on the two main ways to set rates in the freight railroad industry, tariffs, and contracts. It also specifies what enters into the rate-setting process. Section 5 concludes.

1.2 Freight Railroad Companies

The U.S. government classifies freight railroads based on annual revenues. Seven Class I carriers operate nationwide which include companies with operating revenues of $447.6 million or more (in 2017 dollars). Class I railroads make up just 1 percent of freight railroad companies in the country, but around 94 percent of industry revenue, 69 percent of freight rail mileage, and 90 percent of employees are attributed to them. Non-Class I railroads are split into regional and short line railroads. Regional railroads typically operate routes of about 500 miles within two to four states. Shortlines generally exist to interchange traffic with other railroads or to link nearby industries.

There are 7 class I railroads in the U.S., combined they operated over 120 thousand miles of road in 2014. Table 1.1 provides statistics of Class I railroads. BNSF and UP are the two largest companies both by miles of road operated, revenue, and the number of employees. CSXT and NS split the second place. While two Canadian companies, CP and CN, and KCS that serves South combined operated fewer miles of roads than any of the largest four.

Table 1.1: Statistics of Class I Railroads in 2014

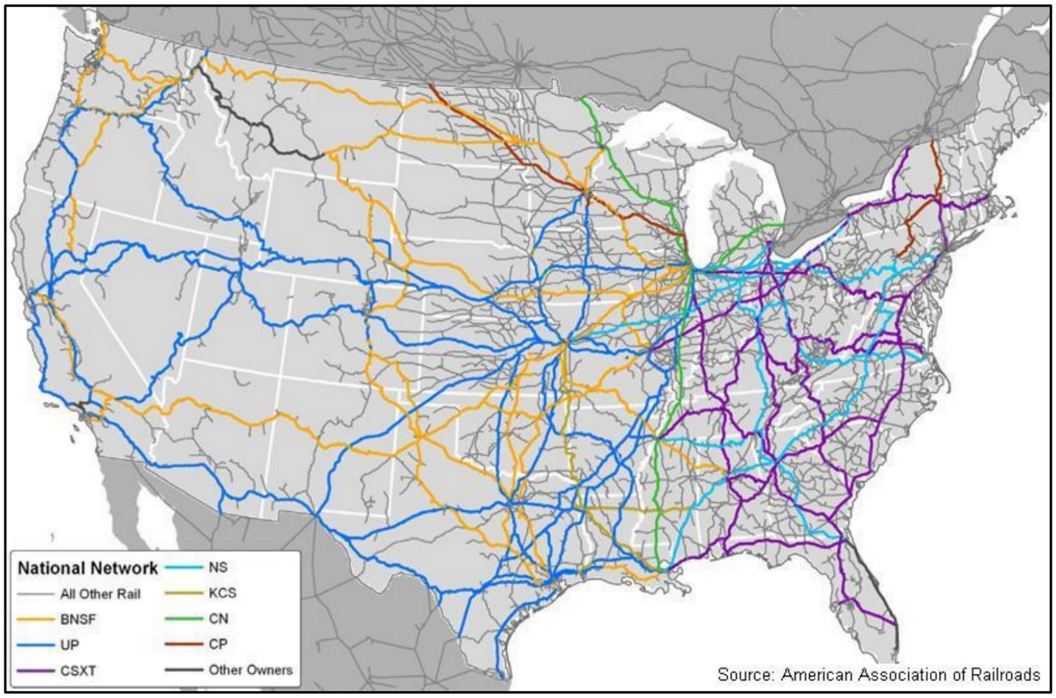
Abbre-viation	Full Name	Miles of Road Operated	Ton-Miles of Freight in M	Operating Revenue in $M	Number of Employees
BNSF	Burlington Northern and Santa Fe Railway	32,643	711,321	23,036	47,770
CN	Canadian National Railway	6,091	66,364	3,550	6,854
CP	Canadian Pacific Railway	5,506	39,856	1,771	3,626
CSXT	CSX Transportation	20,769	245,212	12,342	28,330
KCS	Kansas City Southern Railway	3,339	33,826	1,359	3,150
NS	Norfolk Southern Railway	19,759	205,020	11,624	29,769
UP	Union Pacific Railroad	31,974	549,629	23,975	51,342

Source: STB Class I Railroad Financial & Statistical Reports

Freight railroads are the owners of infrastructure, including tracks, bridges, stations, and junction yards. Apart from the rare cases when haulage or trackage rights are granted to another railroad company, the owner of the tracks is the sole operator on the line. Figure 1.1 illustrates the network of U.S. freight railroads. Two geographical duopolies exist: CSX and Norfolk Southern (NS) compete in the eastern part of the country, while Union Pacific (UP) and BNSF cover the West. Canadian Pacific Railway (CP) offers routes in the northern part of the U.S. and Canada, while Canadian National (CN) connects North with the Gulf of Mexico. Kansas City Southern (KCS) offer routes in the South and Mexico. There is no single transcontinental railroad connecting east and west coast. A customer that need to move freight from coast to coast would need to employ services of two independent railroads with an interchange of freight around Mississippi river tunnel.

Staggers Act deregulated the U.S. rail industry in 1980. It gave greater pricing freedom to railroads, eased and streamlined mergers, and permitted confidential contracts with shippers. The industry is subject to antitrust immunities and is regulated by the Surface Transportation Board (STB). STB is in charge of resolving railroad rate and service disputes, mergers, rail line sales, new line construction and abandonment. Deregulation led to today's concentrated industry. There were 33 class I railroads in 1980, and there are only seven today. This process of consolidation came to at least a temporary end at the turn of the 21st century. In early 2000s BNSF and CN proposed an end-to-end merger to form a first transcontinental railroad in the U.S. The

Figure 1.1: U.S. National Rail Network



Surface Transportation Board (STB) was opposed to the merger and first imposed a temporary freeze on Class I rail mergers and then issued new merger rules that significantly complicated the merger process. No mergers of Class I railroads have been proposed in the meantime.

1.3 Commodities Shipped

In this section, I will dive deeper into nine main commodity groups shipped by railroads, describe dynamics in each of them, leading players and largest geographic markets. I do so by analyzing STB Carload Waybill Sample and additional data sources and reports provided by the industry of a particular commodity group. I have access to the unmasked confidential STB Carload Waybill Sample (CWS) for the years 2003 through 2014. CWS is a stratified sample of individual railroad shipment records submitted to the STB. Only freight rail carriers that terminate at least 4,500 revenue carloads annually submit data to the CWS. The sample includes information about origin and destination, the distance of haul, goods transported, their weight, railroads participating in the movement, revenue collected etc[2]. For a revenue variable, I add all relevant columns from CWS that include Freight Revenue, Fuel Surcharge, and Miscellaneous Charges. All revenues are in 2009 dollars.

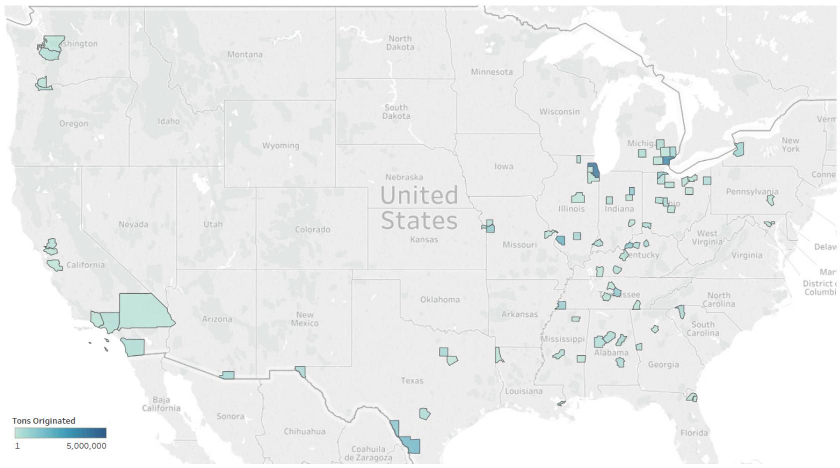
1.3.1 Automotive Products

Automotive products commodity group covers STCC code 371 and includes motor vehicles, passenger car bodies, motor bus or truck bodies, motor vehicle parts and accessories, and truck trailers. Most commonly shipped product in the commodity group in 2014 was passenger motor vehicles (auto) with about 21 million tons shipped. Freight motor vehicles occupied the second place with 8.3 million tons, and auto parts was the third most populous product with about 1.1 million tons shipped. Most of the products in this commodity group are being shipped to or from automobile manufacturing facilities or assembly plants. According to the Association of American Railroads (2018) (AAR), 75% of new cars and light trucks were hauled by freight

[2] Small percentage of interlined traffic in CWS was rebilled: reported as two separate shipments. These shipments were linked back together to match commodity flows in The Freight Analysis Framework. See more details in Appendix.

railroads in 2017. Some auto transport companies that help individuals ship cars also work with freight railroad companies, but that is by far a much lower share of shipments.

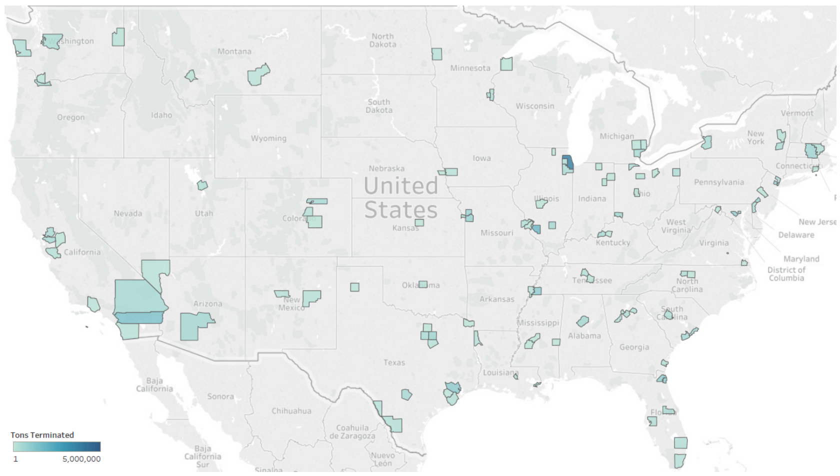
Figure 1.2: Automotive Products Rail Tonnage by Origin County, 2014



Source: STB Carload Waybill Sample

Figures 1.2 and 1.3 indicate origins and destinations of freight railroad shipment by the number of tons shipped in 2014. According to AAR freight railroads serve more than 70 automobile manufacturing facilities and assembly plants in North America. The plants are spread out across the U.S. with General Motors Company operating facilities in Texas, Kentucky, Michigan, Kansas, Indiana, Ohio, Tennessee, and Missouri; Ford Motor Company in Michigan, Illinois, Missouri, Kentucky, and Ohio; Fiat Chrysler Automobiles in Illinois, Michigan, and Ohio; Tesla Motors in California; Toyota Motor Corporation in Kentucky, Indiana, Texas, California, and Mississippi; Honda Motor Company in Ohio, Alabama, and Indiana; Nissan Motor Company in

Figure 1.3: Automotive Products Rail Tonnage by Termination County, 2014

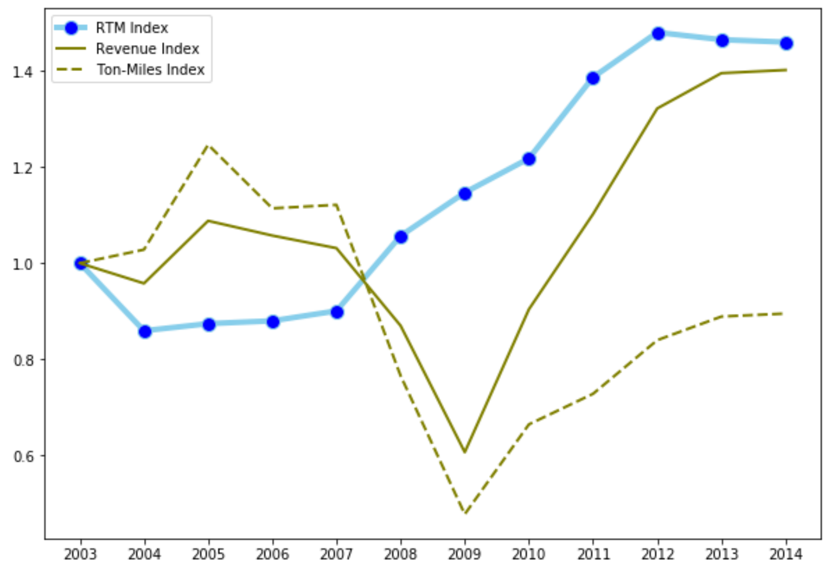


Source: STB Carload Waybill Sample

Tennessee and Mississippi; Subaru Corporation in Indiana; Hyundai Motor Company in Alabama; Kia Motors in Georgia, Volkswagen Group in Tennessee; Volvo Cars, BMW Group, and Daimler AG in South Carolina.

Many automotive products shipments are in carload quantities, in CWS only a handful of waybills had more than one carload. Railroads have designed specialized railcars to move automobiles; they are commonly referred to as autoracks. They usually have two or three decks, and some of them can carry over 20 vehicles. Larger vehicles and parts are often transported on flat cars. The average load per car in the CWS is about 22 tons, and the average distance traveled is about 950 miles. The average revenue per ton-mile ranged from \$0.126 in 2004 to \$0.217 in 2012. Ton-miles per year have significantly dropped during the recession from 37.8 billion in 2007 to 16.1 billion in 2009.

Figure 1.4: Automotive Products Revenue, Ton-Miles, and RTM Trends, 2003-2014



Source: STB Carload Waybill Sample

Ton-miles have been on a recovery path since then, in 2014 they reached 30.2 billion. Revenue also dropped from \$3.5 billion in 2007 to \$2.1 billion in 2009. However, due to the increased rates, it has well surpassed prerecession revenue by 2014. Figure 1.4 shows how total revenue in the commodity group, ton-miles shipped and revenue per ton-mile changes over the years. Variables are normalized to equal to one in 2003.

1.3.2 Chemicals, Fertilizer and Plastic

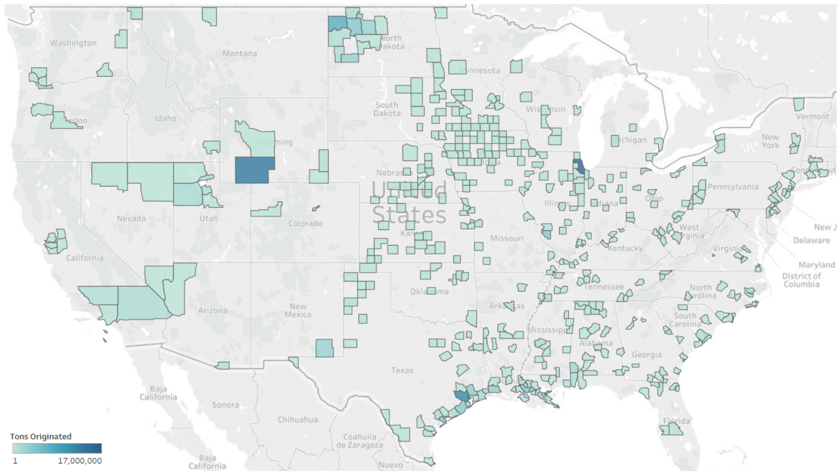
Chemicals are essential to the production of a large number of manufactured products and are used by other major industries such as agriculture, clothing, and water utilities. According to the American Chemistry Council, U.S. accounts for almost 20% of the world chemicals production and is among the top chemical producers in the world.

Chemicals, fertilizer, and plastic commodity group includes 2-digit STCC codes 28 and 49. It covers all chemicals and allied products, and hazardous materials. Major component commodities include organic and inorganic industrial chemicals (3-digit STCC 281, e.g., ammonia, chlorine, other industrial gases, and alcohols), plastics and synthetic fibers (3-digit STCC 282), and agricultural chemicals including fertilizers (3-digit STC 287).

Majority of the shipments in this commodity group are classified as non-hazardous; however, a substantial part is hazardous materials. Most common hazardous chemicals shipped by rail are ammonia, the foundation for the nitrogen fertilizer industry, and chlorine, used in chlorination as a part of municipal water treatment. Transportation of hazardous materials is subject to strict oversight and specific regulations on operating rules and tank car standards that can be costly to railroads.

According to Energy Department Office of Energy Efficiency & Renewable Energy (2018)he production of basic chemicals is concentrated near the regions where petroleum and natural gas materials are produced, mainly along the Gulf Coast, the Delaware Valley, and the Midwest. Chemical products derived from petroleum (petrochemicals) are primarily produced in Texas and Louisiana. Other chemicals, such as plastics, pharmaceuticals, and fertilizers, are produced in a variety of locations throughout the country. Figure

Figure 1.5: Chemicals, Fertilizer and Plastic Rail Tonnage by Origin County, 2014



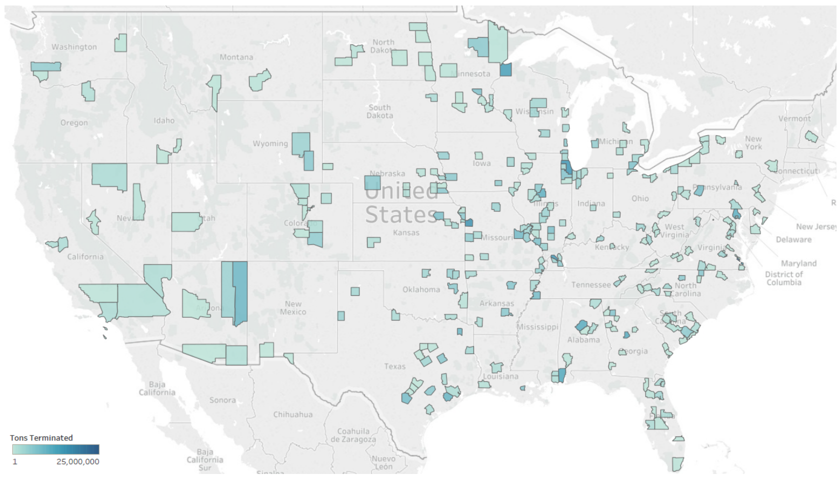
Source: STB Carload Waybill Sample

1.5 shows the origins of rail shipments by county and tonnage. The origins roughly overlay with the leading chemical production regions.

End-users of the chemicals are spread among different industries and geographical locations. Chemical shipment destinations are very widely dispersed. Figure 1.6 shows rail shipment destinations for chemicals, fertilizer, and plastic commodity group.

Small sizes of chemical shipments and regulations on hazmat materials do not allow shippers to organize lower-cost rail shipments to a single destination and use economies of scale that rail transportation provides. Truck transportation of chemicals usually has lower cost and offers more flexibility. Some chemical companies even own truck fleet to reduce the cost of shipment. Trucking is most widely used for small volume shipments. According to

Figure 1.6: Chemicals, Fertilizer and Plastic Rail Tonnage by Termination County, 2014

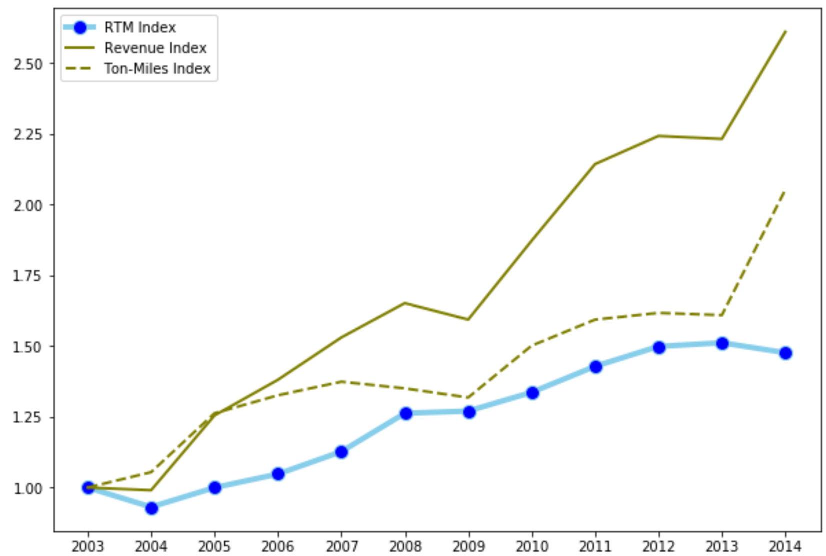


Source: STB Carload Waybill Sample

the American Chemistry Council (2017), more than half of all chemicals are transported by truck, with rail and water transportation splitting the other half.

Many chemical shipments are in rather small quantities; the CWS annual averages have ranged from 1.1 to 1.48 carloads per waybill. Hopper and tank cars are most commonly used to move chemicals. The average load per car in the CWS is about 94 tons, and the average distance traveled is about 850 miles. The average revenue per ton-mile ranged from \$0.045 in 2004 to \$0.073 in 2013. Ton-miles per year were steadily growing from 83.3 billion in 2003 to 171 billion in 2014 with a slight drop during the recession. Revenue also grew from \$3 billion in 2003 to\$7.9 billion in 2014. Figure 1.7 shows how total revenue in the commodity group, ton-miles shipped and revenue per

Figure 1.7: Chemicals, Fertilizer and Plastic Revenue, Ton-Miles, and RTM Trends, 2003-2014



Source: STB Carload Waybill Sample

ton-mile changes over the years. Variables are normalized to equal to one in 2003.

1.3.3 Coal

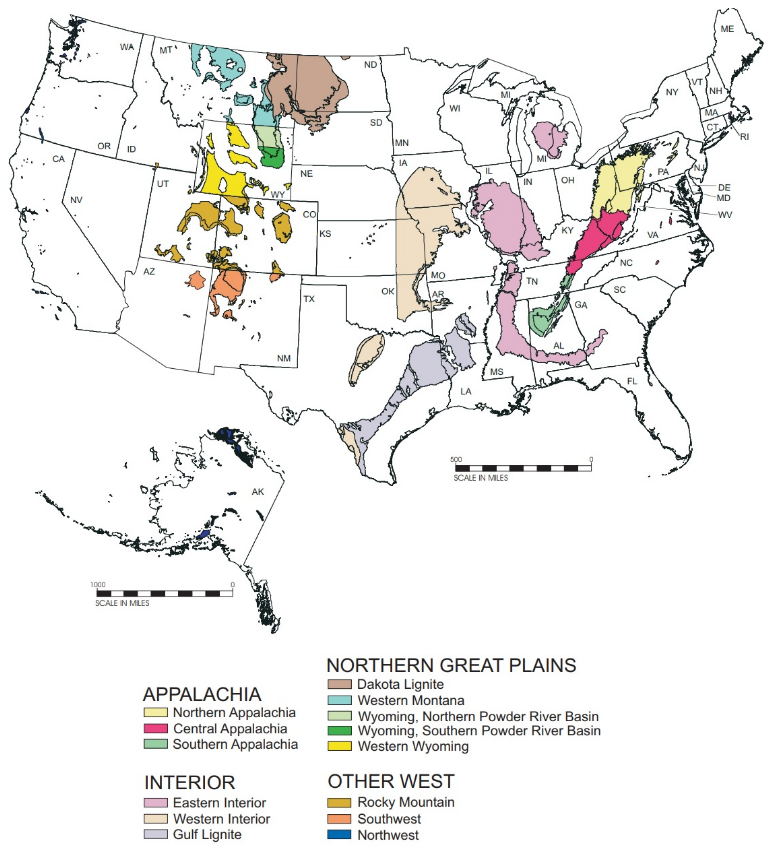
Coal is a leading commodity in terms of tons originated by freight railroads. It accounted for approximately one-third of billed tons moved by freight railroads in 2014. However, due to being a low-value bulk commodity, coal occupies the second place by revenue. To provide the coal industry overview, I will be mainly relying on the U.S. Energy Information Administration (EIA) Coal Data Browser.

Coal is one of the primary energy sources in the U.S. Its production was at the record levels in the early 2000s, with 1,171 million tons produced in 2008. Since then, total production had declined to about 1,000 million tons in 2014. Figure 1.8 shows the major U.S. coal supply regions. Coal production is highly concentrated in Powder River Basin, that spans through southeast Montana and northeast Wyoming; Central and Northern Appalachia, located in the eastern U.S., along the length of Appalachia (in the states of Ohio, the western part of Pennsylvania, West Virginia, the eastern part of Kentucky, Tennessee, and Alabama); Illinois Basin, that includes Illinois, Indiana, and west Kentucky; Uinta Basin of Colorado and Utah.

Figure 1.9 describes production of coal by basin from 2003 to 2014. Powder River Basin (PRB), where annual production of coal accounted for approximately 42% of the country's production in 2014, had reached a peak of coal production in 2008 and an immediate decline after that. The demand for PRB coal was rising because the Clean Air Act was limiting sulfur dioxide emissions, and PBR coal has low sulfur content. Illinois Basin is the only region where coal production was constantly growing in the years of interest. Some of the reasons for the growth is that coal there is cheaper to mine, and the region has a favorable position for shipment of coal to ports for exports. Central Appalachia has seen the highest level of decline in production, in 2008 it accounted for about 22% of the U.S. coal production, while in 2014 for only 12%.

Electric Power sector is by far the biggest consumer of coal. In 2014

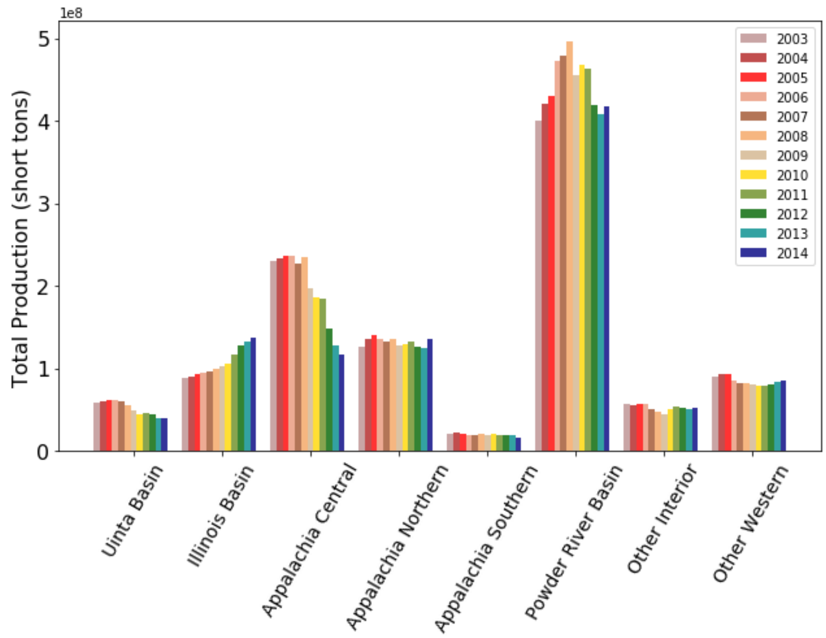
Figure 1.8: Major U.S. Coal Supply Regions



Source: U.S. Energy Information Administration, Office of Energy Analysis. EIA-AEO 2014, Figure 7.

93% of coal was purchased to produce electricity at coal-fired generating units. According to EIA, some of the largest coal-fired plants receive 1-2 unit trains of coal each day, with approximately 115 cars in a train and 116 tons of coal in an average car, resulting in more than 26,000 tons of coal burned a day. However, consumption by Electric Power sector has fallen by about 15% from 2003 to 2014. Coke plants and other industrial users each consume about

Figure 1.9: Coal Production by Basin, 2003-2014

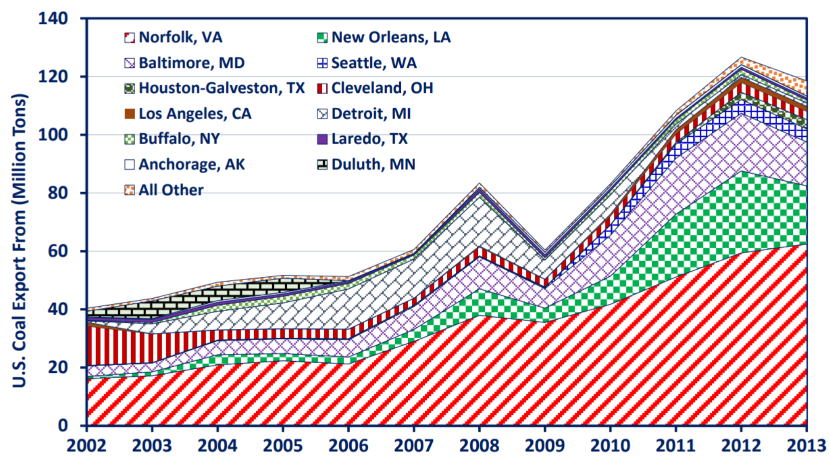


Source: U.S. Energy Information Administration. List of mines for all coal, total, United States, all mine statuses.

2-5 % of coal. Texas is the biggest consumer of coal, with 101 million tons consumed in 2014. Illinois occupies the second place with 51 million tons of coal consumed by the electric power sector.

The U.S. imports coal in small quantities. Some coal-burning power plants located close to seaports sometimes find it cheaper to import coal from other countries than to obtain coal from U.S. coal-producing regions. Imports had fallen from 25 million tons in 2003 to about 11 million tons in 2014. Exports of coal have been steadily growing from 2003 to 2012 and have fallen slightly in 2014. In 2012 the U.S exported about 126 million tons of coal. The rise in export of coal was mainly due to entering European and Asian markets. According to EIA, the recent drop in export is due to lower European demand and increased global supply. The largest consumers of U.S. coal in 2014 were Brazil, South Korea, the Netherlands, Canada, Italy, United Kingdom, and Japan. As shown in figure 1.10, growing demand from Europe and Asia resulted in an increased tonnage of coal passing through Atlantic and Gulf ports.

Figure 1.10: U.S. Coal Exports by Customs District, 2002-2013

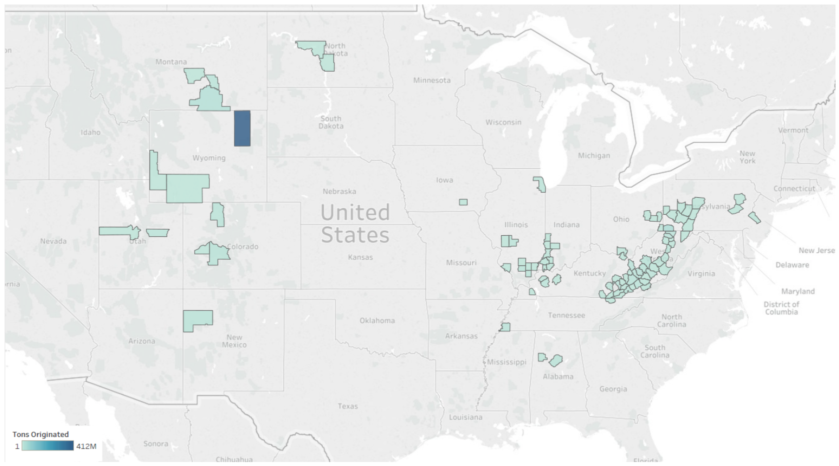


Source: Coal-by-Rail: A Business-as-Usual Reference Case, Argonne, Energy Systems Division

Origins of freight railroad movements of coal are shown in figure 1.11. They mostly overlap with major coal basins. Figure 1.12 shows coal termination counties by volume. They are spread around the country with some concentration in ports, where coal leaves the country for export.

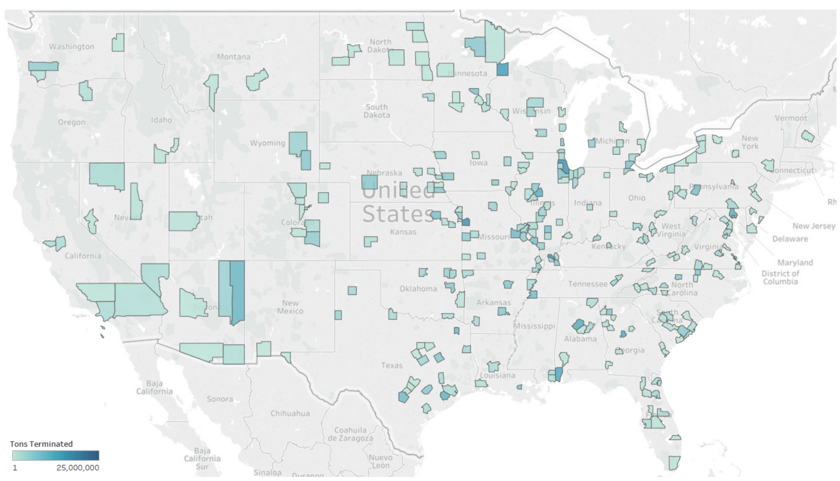
Figure 1.13 shows dynamics of coal transportation by mode. Majority

Figure 1.11: Coal Rail Tonnage by Origin County, 2014



Source: STB Carload Waybill Sample

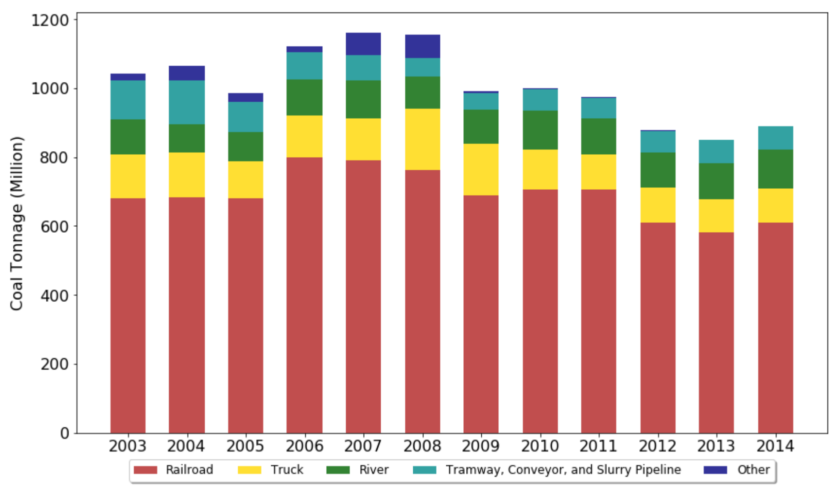
Figure 1.12: Coal Rail Tonnage by Termination County, 2014



Source: STB Carload Waybill Sample

of the coal is being moved by freight railroads. In 2014 the share of the railroad in coal transportation market was 68.5%. Truck and river barges split the second place, with 11 and 13% respectively. Transportation by water is considered to be the cheapest option when available. The share of coal moved by river slowly but steadily increased from about 8% in 2004 to about 13% in 2014. Wyoming, a state that produces the largest amount of coal in the U.S. is located far from waterways, and most electrical utilities, therefore, the railroad is the dominating mode of transportation in the region. Conveyors and Tramways are primarily used for short distances between coal mines and nearby coal-burning facilities.

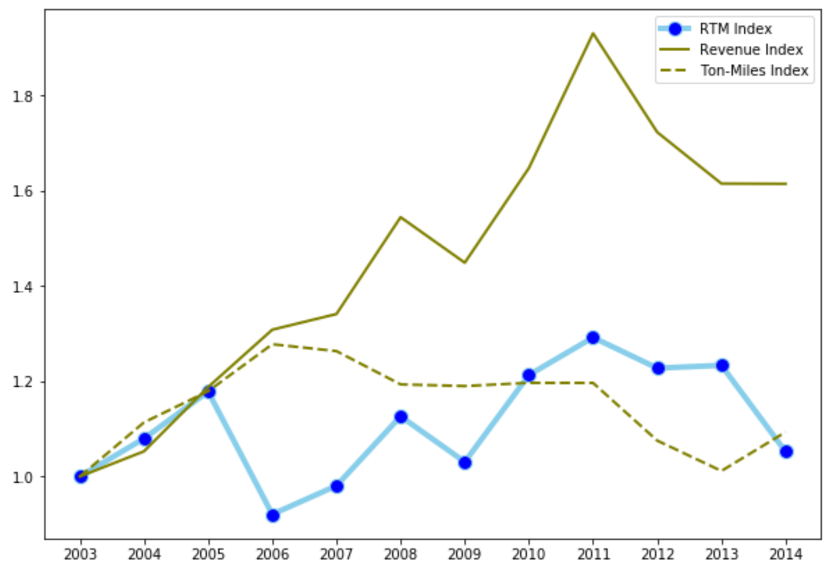
Figure 1.13: U.S. Coal Tranport by Mode, 2002-2013



Source: U.S. Energy Information Administration. Annual Coal Distribution Report

Most of the coal is being moved in unit trains. The unit train usually consists of 100-150 cars that are carried from a single origin to a single destination. Gondola and hopper cars are usually used to transport coal. Gondola has 121 tons carrying capacity, while hopper car has 102. The most significant volume of coal is being transported from Powder River Basin (specifically Casper BEA Area) to coal-fired power plants and exporting points in St. Louis, Chicago-Gary-Kenosha, Kansas City, and Houston BEA Areas.

Figure 1.14: Coal Revenue, Ton-Miles, and RTM Trends, 2003-2014



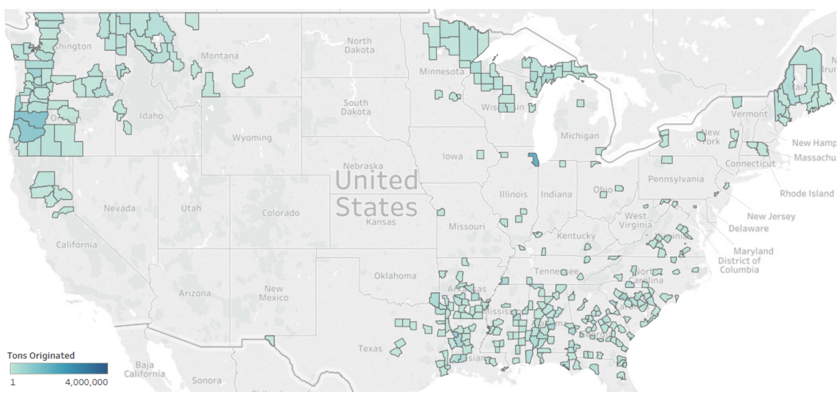
Source: STB Carload Waybill Sample

The average distance of coal shipments grew from 640 in 2003 to 840 in 2014. This is mainly due to the shift to production in PRB. The average revenue per ton-mile ranged from \$0.029 in 2006 to \$0.040 in 2011. Ton-miles shipped by freight railroads per year peaked in 2006 at 713 billion and were falling ever since. Revenue grew until 2011 and fell in recent years. Figure 1.14 shows how total revenue in the commodity group, ton-miles shipped and revenue per ton-mile changes over the years. Variables are normalized to equal to one in 2003.

1.3.4 Construction and Forest Products

Construction and forest products commodity group includes 2-digit STCC codes 24 and 26. It covers primary forest or wood raw materials, all lumber and wood products, all products from pulp mills, paper, paperboard or fiberboard, containers or boxes, and building paper or board. These products are vital in the construction, manufacturing, and shipping segments of the U.S. economy, and demand is highly correlated to economic growth and demand for new residential and non-residential buildings.

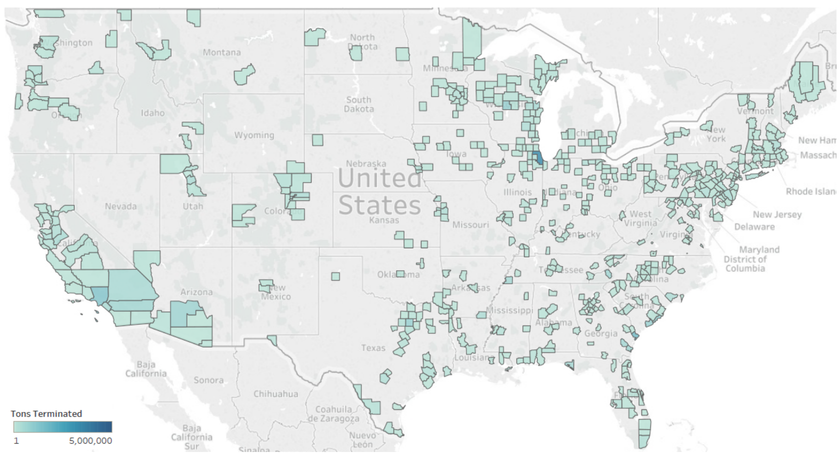
Figure 1.15: Construction and Forest Products Rail Tonnage by Origin County, 2014



Source: STB Carload Waybill Sample

Most production of construction and forest products is concentrated in regions where substantial forest resources are located, such as Pacific Northwest (Washington, Oregon, Northern Idaho, and parts of Montana), Upper Midwest (northern Minnesota, Wisconsin, and Michigan), New England (mainly Maine), and parts of Southeastern U.S.(Louisiana, Arkansas, Mississippi, Alabama, Georgia, North and South Carolina, and Virginia). Figure 1.15 shows the origin of rail shipments by county and tonnage. Oregon is the top exporter with over 5.4 million tons of construction and forest products originating in the state in 2014. Alabama takes second place with 3.5 million tons.

Figure 1.16: Construction and Forest Products Rail Tonnage by Termination County, 2014

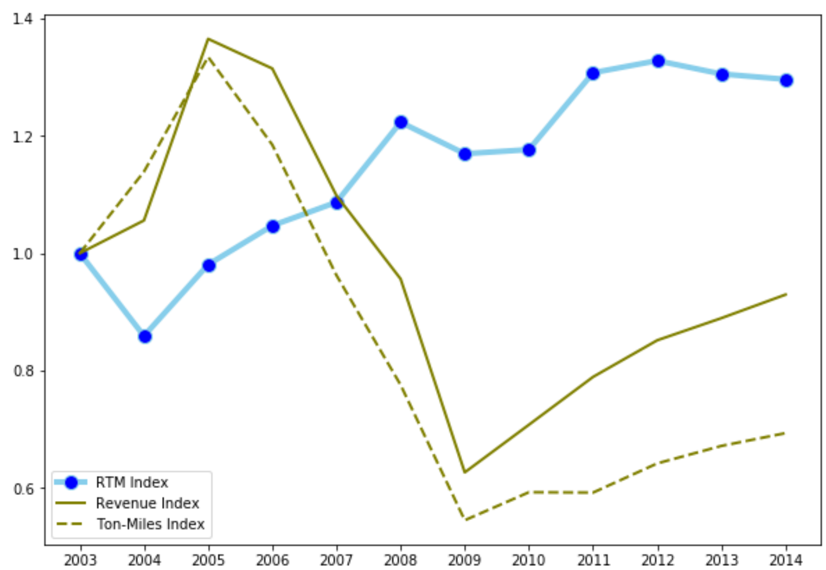


Source: STB Carload Waybill Sample

End-users of construction and forest products are mainly located in densely populated areas, manufacturing zones, and ports. Figure 1.6 shows rail shipment destinations for construction and forest products commodity group. California by far is the largest importer with 3.8 million tons of rail shipment terminating within the state in 2014.

Construction and forest products are primarily shipped by truck. According to the Freight Analysis Framework, almost 90% of construction and forest products are transported by truck, with rail being the second most popular mode with about 7% modal share.

Figure 1.17: Construction and Forest Products Revenue, Ton-Miles, and RTM Trends, 2003-2014



Source: STB Carload Waybill Sample

Many construction and forest products are in carload quantities, with only a few waybills having more than one carload. Box and flat cars are most commonly used to move products in this commodity group. The average load per car in the CWS is about 80 tons, and the average distance traveled is about 950 miles. The average revenue per ton-mile ranged from \$0.045 in 2004 to \$0.068 in 2014. Ton-miles per year were growing until 2005 where they reached 68 billion, declined until 2009 to 28 billion, and slightly recovered to 35 billion in 2014. Total market revenue followed the trend of ton-miles. It peaked at

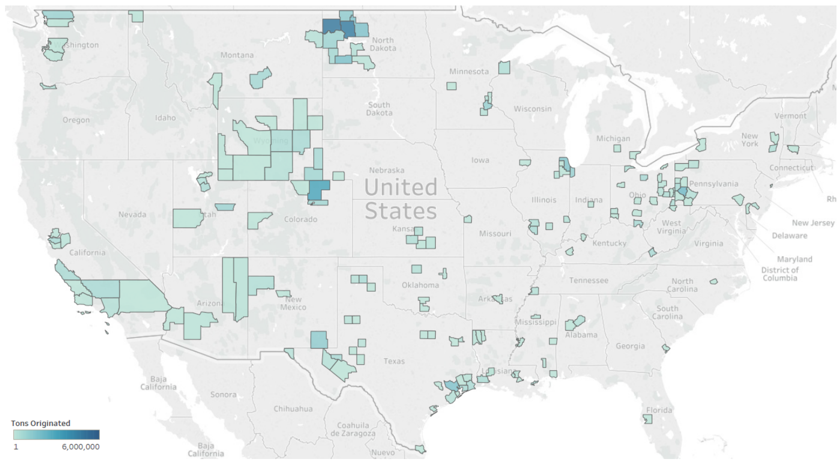
\$2.5 billion in 2006, bottomed at \$1.2 billion in 2009, and partially recovered to \$.8 billion in 2014. Figure 1.17 shows how total revenue in the commodity group, ton-miles shipped and revenue per ton-mile changes over the years. Variables are normalized to equal to one in 2003.

1.3.5 Energy Products and Fuels

Energy products and fuels commodity group includes 3-digit STCC code 291, 2-digit STCC 13, and STCC codes 29911, 29913 and 29914. The first group is petroleum products; they include crude and all products of petroleum refining, such as gasoline, jet or high volatile fuels, kerosene, distillate fuel oil, lubricating oils and greases, asphalt pitches or tars, residual fuel oils, and liquefied gases. The second group includes coal or coke briquettes, petroleum coke, and coke produced from coal. Composition of products shipped within this commodity group shifted a lot over the years. For example, petroleum oil or shale oil (STCC 1311110) was the leader in terms of tons shipped by freight railroads, with almost 25 million tons hauled. However, there are no shipments with this commodity code before 2010. This is a result of the shale oil boom. On the other hand, synthetic fuel derived from coal (STCC 2991191) was occupying the first place by tons shipped in 2003, with close to 5 million tons shipped, and no waybills with this commodity group were found in CWS after 2007.

Figure 1.18 shows the origin of rail shipments by county and tonnage. They are concentrated around the major oil fields in states of North Dakota,

Figure 1.18: Energy Products and Fuels Rail Tonnage by Origin County, 2014

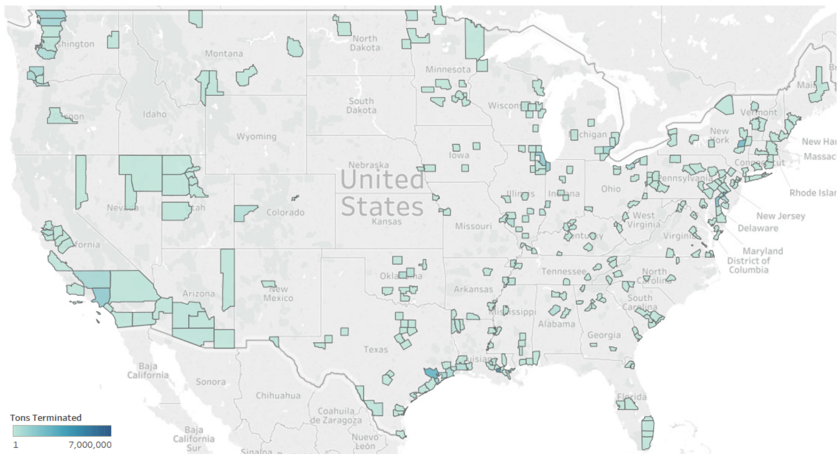


Source: STB Carload Waybill Sample

New Mexico, Texas, California, and Colorado. Additionally, there are several coke plants located in Illinois, Alabama, Michigan, Ohio, Indiana, Ohio, Pennsylvania, and Virginia.

The vast majority of crude oil produced in the U.S. is moved to petroleum refineries. They are heavily concentrated along the Gulf Coast of Texas and Louisiana. A smaller number of refineries are located in California, Washington, Illinois, and along the East Coast. Coke products are used mainly in iron ore smelting. However, with the development of new technologies, natural gas steadily replaces coke in the U.S. steelmaking. Major steel-makers are located in the states of Minnesota, Kentucky, Pennsylvania, Ohio, Michigan, Indiana, Texas, North Carolina, and others. Figure 1.19 shows termination of rail shipments by county and tonnage.

Figure 1.19: Energy Products and Fuels Rail Tonnage by Termination County, 2014

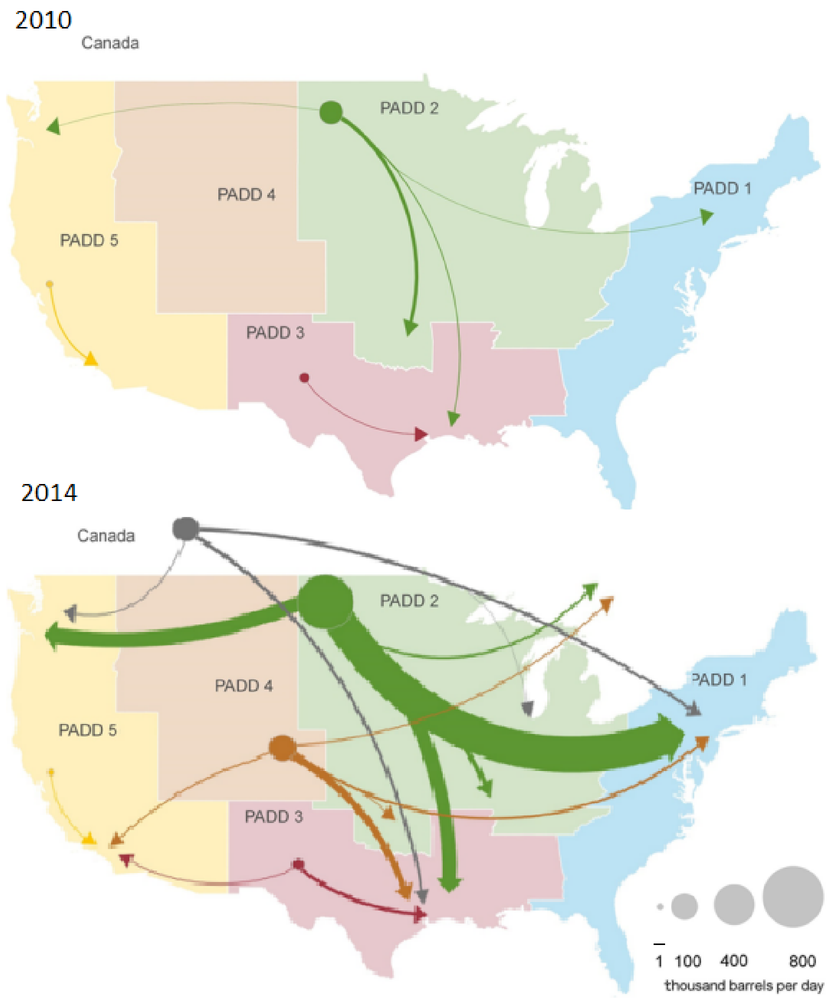


Source: STB Carload Waybill Sample

Energy products and fuels are primarily shipped by pipeline, with over half of the tonnage being shipped this way. Truck occupies the second place and takes about the quarter of the modal share. Trucks are usually used to carry smaller capacities for short distances. Share of rail in energy products and fuels shipments is relatively small, with about 5-7% of shipment. Rail is a common way to move fuels for a long distance to areas where they do not have pipelines set up. However, shipments of crude oil by rail have been growing sharply in recent years. Figure 1.20 shows the main flows of crude oil by rail in 2010 and 2014. According to EIA, crude-by-rail movements in the U.S. and between the U.S. and Canada have doubled between 2010 and 2014.

Energy products and fuels are usually shipped in relatively small quantities; the average number of carloads per waybill varied from 1.68 in 2009

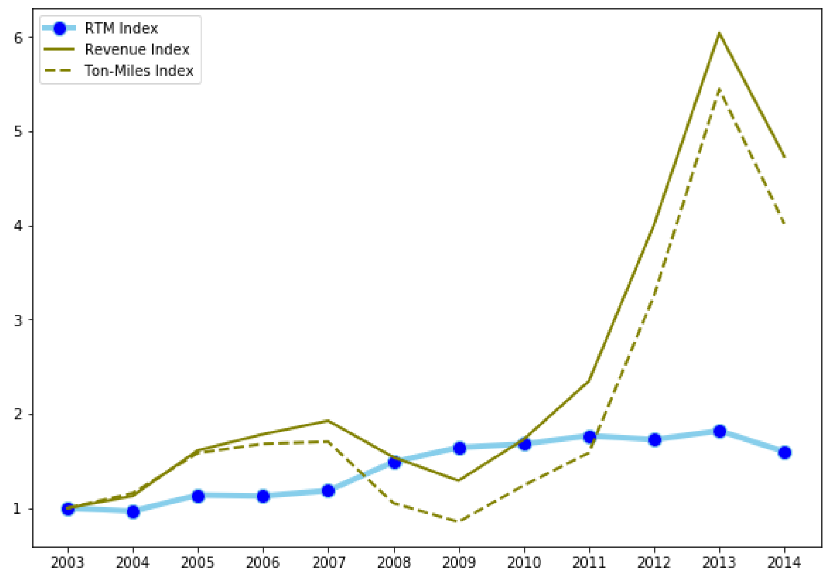
Figure 1.20: Crude-by-Rail Movements, 2010 and 2014



Source: U.S. Energy Information Administration based on data from the Surface Transportation Board and other information.

to 3.16 in 2013. Tank cars are most commonly used to move products in this commodity group. The average load per car in the CWS is about 80 tons. The average distance grew from 697 in 2003 to 866 in 2014. The average revenue per ton-mile ranged from $0.046 in 2003 to $0.063 in 2013. Ton-miles per year

Figure 1.21: Energy Products and Fuels Revenue, Ton-Miles, and RTM Trends, 2003-2014



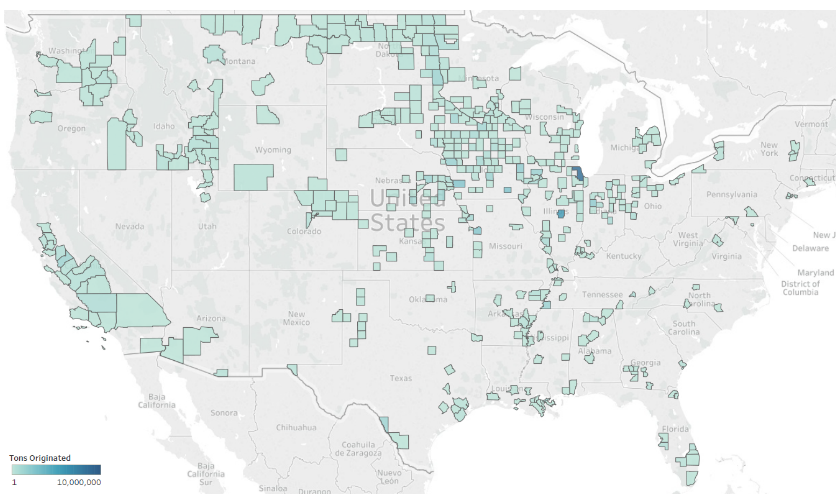
Source: STB Carload Waybill Sample

were growing until 2006, declined during the recession, and almost recovered in the recent years to 2006 level. Ton-miles grew from 14 billion in 2003 to 24 billion in 2007, dropped to 12 billion in 2009, and skyrocketed to 77 billion in 2013. Total market revenue followed the trend of ton-miles. Figure 1.21 shows how total revenue in the commodity group, ton-miles shipped and revenue per ton-mile changes over the years. Variables are normalized to equal to one in 2003.

1.3.6 Food and Beverages

Food and beverages commodity group includes 2-digit STCC codes 01, except 0113 and 01144, and 02. The first group includes all farm products except grains and soybeans. The second group includes food and kindred products, and grain mill products, such as flour, prepared feed, cereal preparations, milled rice, wet corn milling or sorghum products, soybean cake. Soybean cake that is used in animal feeds was a leading product shipped in the commodity group in 2014, with 15 million tons shipped. Corn syrup was in second place with 10 million tons.

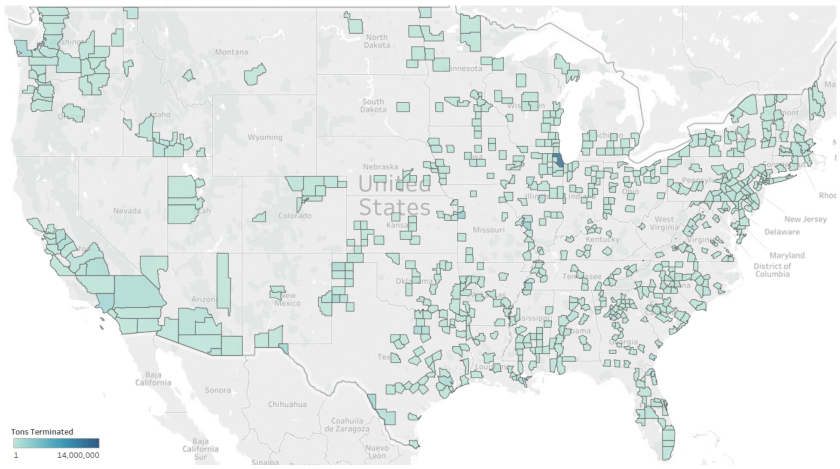
Figure 1.22: Food and Beverages Rail Tonnage by Origin County, 2014



Source: STB Carload Waybill Sample

Figure 1.22 shows the origin of rail shipments by county and tonnage. Shipments mostly originated in Midwest, and parts of Northwest and California.

Figure 1.23: Food and Beverages Rail Tonnage by Termination County, 2014



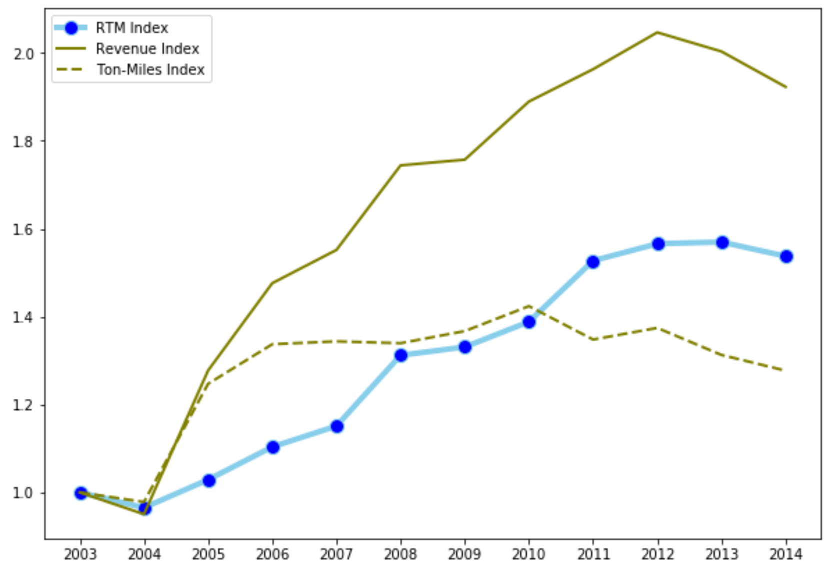
Source: STB Carload Waybill Sample

Figure 1.23 shows termination of rail shipments by county and tonnage. Destination locations are spread around the country and clustered around densely populated and agricultural areas.

Food and Beverages are primarily shipped by truck. According to the Freight Analysis Framework, almost 90% are transported by truck, with rail being the second most popular mode with about 7-10% modal share.

Food and Beverages commodity group is among the products that are usually shipped in small quantities; the average number of carloads per waybill varied from 1.24 in 2003 to 1.37 in 2014. Hopper and tank cars are most commonly used to move products in this commodity group. The average load per car in the CWS is about 90 tons, and the average distance traveled is about 1050 miles. The average revenue per ton-mile grew from $0.036 in 2003

Figure 1.24: Food and Beverages Revenue, Ton-Miles, and RTM Trends, 2003-2014



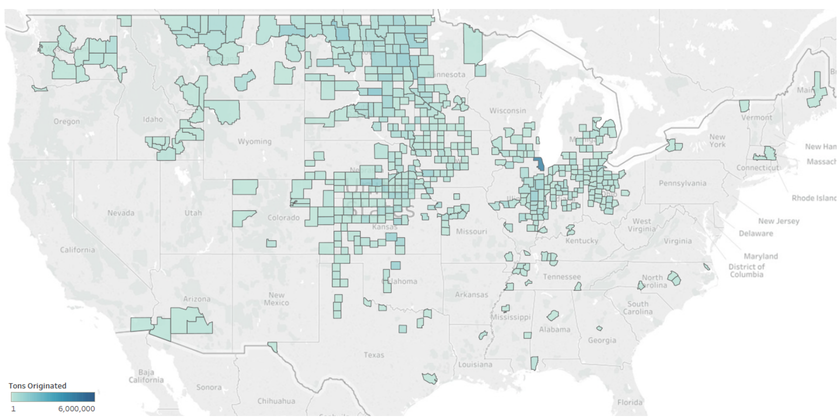
Source: STB Carload Waybill Sample

to $0.058 in 2013. Ton-miles per year were growing until 2010 and slightly declined after that. Total market revenue was almost constantly increasing from 2003 to 2014 primarily due to price increases. Total commodity revenue increased from $2 to $3.8 billion dollars from 2003 to 2014. Figure 1.24 shows how total revenue in the commodity group, ton-miles shipped and revenue per ton-mile changes over the years. Variables are normalized to equal to one in 2003.

1.3.7 Grains and Feeds

Grains and feeds commodity group includes STCC 0113 and 01144, grains (wheat, corn, oats, sorghum, etc.) and soybeans respectively. Non-organic corn, wheat, and soybeans are the most common products shipped with the volume of 48.5, 27.6, and 21.7 million tons respectively. According to USDA[3], corn is mostly consumed domestically; its primary use is as animal feed. A significant fraction of the U.S. wheat is exported. The exports of corn are high as well.

Figure 1.25: Grains and Feeds Rail Tonnage by Origin County, 2014



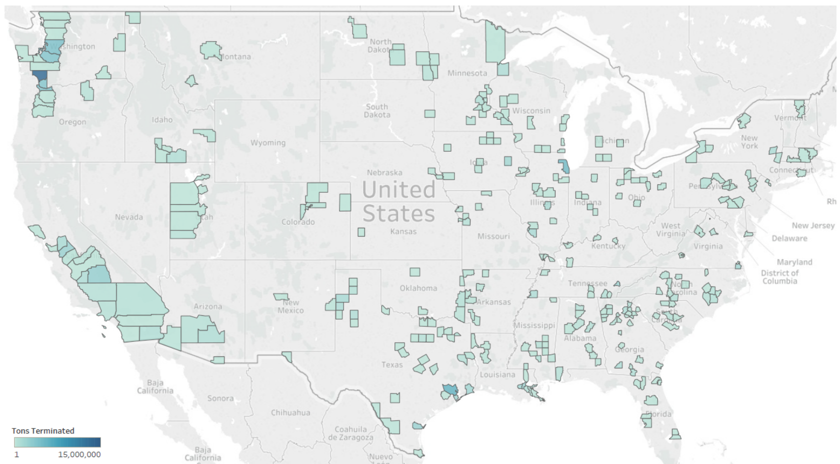
Source: STB Carload Waybill Sample

Figure 1.25 shows the origin of rail shipments by county and tonnage. Shipments mostly originated in Midwest and Northwest. According to USDA[4],

[3]U.S. Department of Agriculture, Foreign Agricultural Service, Production, Supply and Distribution.

[4]U.S. Department of Agriculture, National Agriculture Statistics Service, 2002 Census of Agriculture

Figure 1.26: Grains and Feeds Rail Tonnage by Termination County, 2014



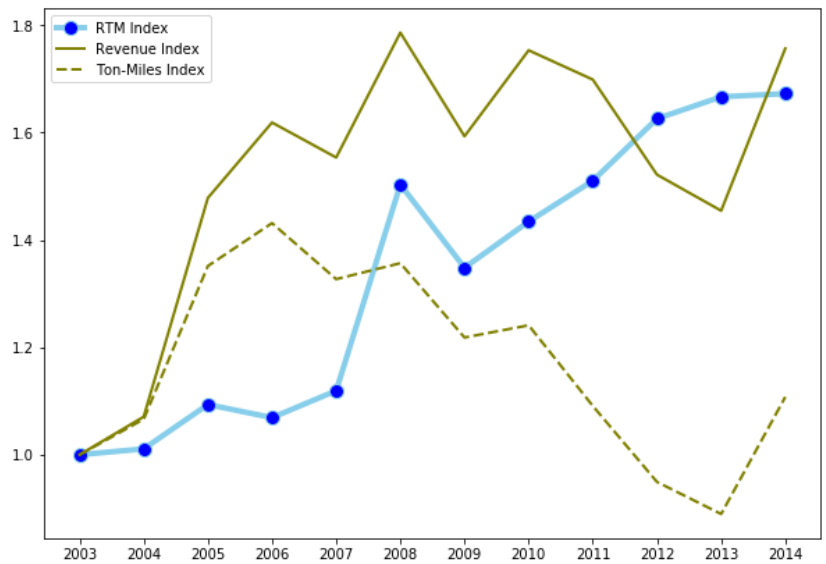
Source: STB Carload Waybill Sample

approximately two-thirds of U.S. corn is produced in the "Corn Belt" states of Iowa, Illinois, Nebraska, Minnesota, and Indiana. U.S. wheat production is concentrated in the northern and central plains.

Figure 1.26 shows termination of rail shipments by county and tonnage. Destination locations are spread around the country with clusters around export facilities.

Grains and feed are primarily shipped by truck. Rail is the second most populous mode of transportation with about 20% modal share. Freight in this commodity group is sometimes shipped in unit trains to reduce the cost of shipment. In recent years railroad companies have been increasingly pushing shippers to use unit trains. The share of trains with 100 or more carloads in CWS in grains and feed commodity group had increased from 3.9% in 2003

Figure 1.27: Grains and Feeds Revenue, Ton-Miles, and RTM Trends, 2003-2014



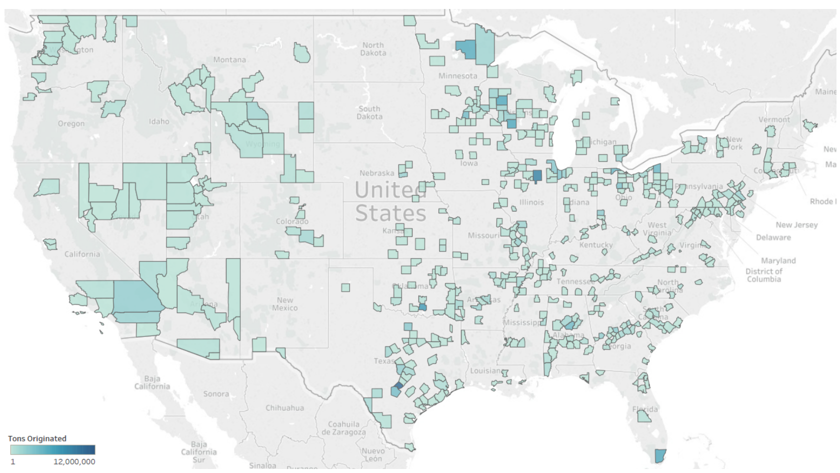
Source: STB Carload Waybill Sample

to 9.4% in 2014. Hopper cars are most commonly used to move grains and feed. The average load per car in the CWS is about 100 tons, and the average distance traveled is about 900 miles. The average revenue per ton-mile grew from \$0.032 in 2003 to \$0.053 in 2014. Ton-miles per year were growing until 2006, and have been declining since then. Total market revenue has not been falling much due to the increased price per ton-mile shipped. Figure 1.27 shows how total revenue in the commodity group, ton-miles shipped and revenue per ton-mile changes over the years. Variables are normalized to equal to one in 2003.

1.3.8 Metals and Minerals

Metals and minerals commodity group includes 2-digit STCC codes 10, 14, 32, 33, 34. These include metallic ores (all metallic ores, such as iron, copper, lead, zinc, gold, silver, bauxite or aluminum, manganese, tungsten, and chromium ores), crushed stone, sand and gravel, nonmetallic minerals (clay, phosphate rock, rock salt, etc.), stone, clay and glass products, metals and products (galvanized, and fabricated metal products).

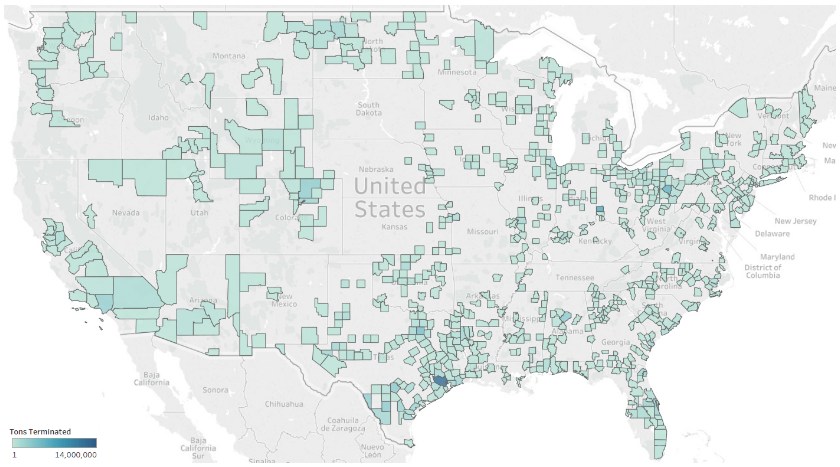
Figure 1.28: Metals and Minerals Tonnage by Origin County, 2014



Source: STB Carload Waybill Sample

Figure 1.28 shows the origin of rail shipments by county and tonnage. Figure 1.29 shows termination of rail shipments by county and tonnage. Both origin and destination locations are spread around the country. Texas and Wisconsin are two leaning states in terms of tonnage both originated, and Texas and Ohio lead by terminated tons. Texas originated 27 million tons and

Figure 1.29: Metals and Minerals Tonnage by Termination County, 2014

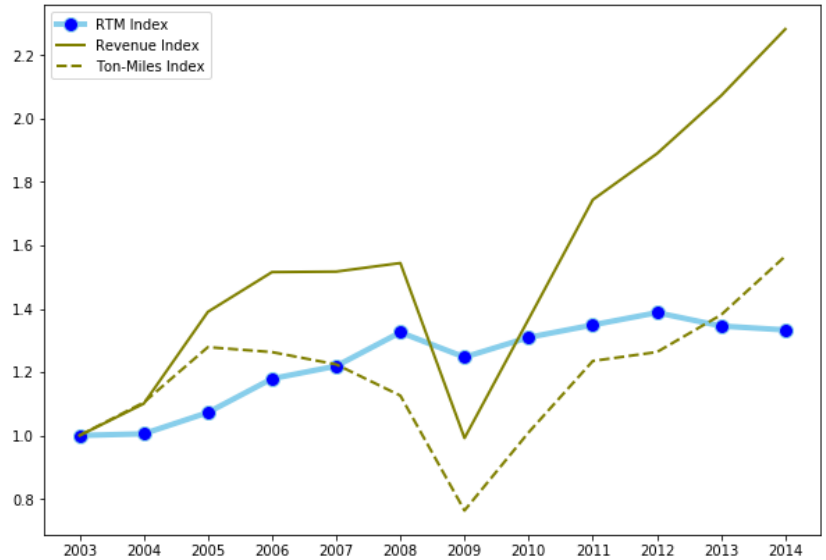


Source: STB Carload Waybill Sample

terminated 61 million tons in 2014, while Wisconsin originated 21, and Ohio terminated 17 million tons.

Metals and minerals are primarily shipped by truck. Rail is the second most populous mode of transportation with about 5-10% modal share. Freight in this commodity group is sometimes shipped in multiple carloads but rarely in unit trains. The average number of carloads per waybill from 2003 to 2014 was about 2.5. Box, gondola, Hopper, and Flat cars are most commonly used to move metals and minerals. The average load per car in the CWS is about 95 tons, and the average distance traveled is about 650 miles. The average revenue per ton-mile grew from \$0.049 in 2003 to \$0.065 in 2014. Ton-miles per year dropped during the recession, but have recovered since. Total market revenue has grown from \$2.6 billion in 2003 to \$5.9 billion in 2014. Figure 1.30 shows how total revenue in the commodity group, ton-miles shipped and

Figure 1.30: Metals and Minerals Revenue, Ton-Miles, and RTM Trends, 2003-2014



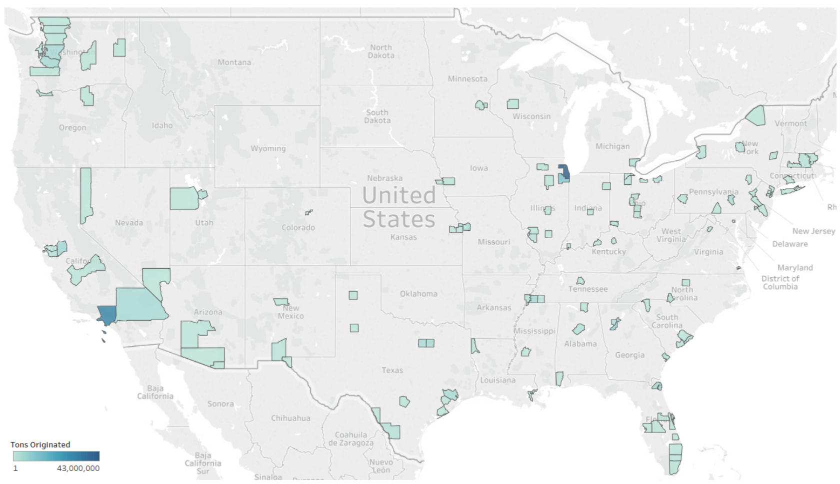
Source: STB Carload Waybill Sample

revenue per ton-mile changes over the years. Variables are normalized to equal to one in 2003.

1.3.9 Intermodal

Intermodal shipments are defined as shipments in rail trailer-on-flatcar (TOFC) and container-on-flatcar (COFC). TOFC is a practice of loading an over the highway truck trailers onto a specialized railway flatcar; it is the most basic form of intermodal transportation. COFC incorporates loading a shipping container onto a flat car. The popularity of COFC has been growing over the past years. Railroads have been developing infrastructure to incorporate double-stacking, where each flat car can carry two layers of intermodal containers. Intermodal containers carry a wide variety of products. The vast majority of movements (over 60%) are recorded as miscellaneous mixed shipments. Other shipments include containerized imported and exported goods and reverse flow of trailers and containers.

Figure 1.31: Intermodal Tonnage by Origin County, 2014

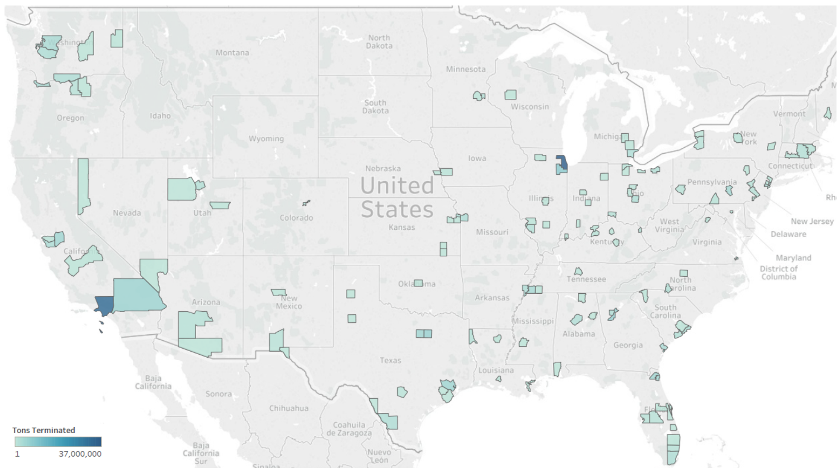


Source: STB Carload Waybill Sample

Figures 1.31 and 1.32 shows origins and terminations of rail shipments by county and tonnage. Both origin and termination locations are spread around the country with major clusters around seaports. The majority of intermodal traffic travels to or from California, Illinois, Texas, and Georgia.

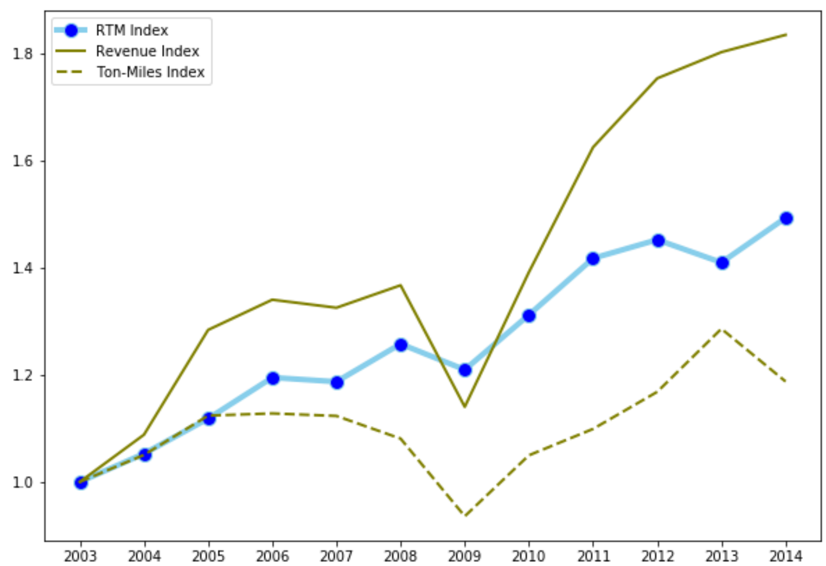
Intermodal shipments are always billed as single-carload shipments, even multiple containers or trailers are placed by a shipper on the same train to the same destination. Therefore, I cannot observe trends in shipment size

Figure 1.32: Intermodal Tonnage by Termination County, 2014



Source: STB Carload Waybill Sample

Figure 1.33: Intermodal Revenue, Ton-Miles, and RTM Trends, 2003-2014



Source: STB Carload Waybill Sample

other than tons per carload. The average load per car in the CWS is about 14 tons, and the average distance traveled is about 1400 miles. The average revenue per ton-mile grew from \$0.056 in 2003 to \$0.083 in 2014. Ton-miles per year dropped during the recession, but have recovered since. Total market revenue had grown from \$8.6 billion in 2003 to \$15.9 billion in 2014. Figure 1.33 shows how total revenue in the commodity group, ton-miles shipped and revenue per ton-mile changes over the years. Variables are normalized to equal to one in 2003.

1.4 Rail Rates: Tariffs and Contracts

The Interstate Commerce Commission (ICC) was established in 1887. Initially, it was created to regulate the rates that railroads charged shippers and ensure that the rates were reasonable. Later, ICC's authority was expanded to regulate other modes of commerce, such as interstate bus and telephone companies. By 1970s, the freight railroad industry reached an economic slowdown. The costs were rising, and it became harder to compete with motor carriers. The railroads were losing share to other modes of transportation and could not easily adjust their rates and capital structure. A series of bankruptcies have hit the industry as a result. To revive freight traffic and make railroads more competitive the Railroad Revitalization and Regulatory Reform Act of 1976 and the Staggers Rail Act of 1980 were executed. These laws substantially deregulated the industry and gave railroads flexibility in setting rates. After the deregulation companies were able to use differentiated pricing and set rates according to the competitive environment. Additionally, railroads and shippers now could enter into confidential contracts to set terms and rates. In 1995 ICC was terminated and transferred its regulatory functions to newly created Surface Transportation Board (STB). The STB has been serving as the freight railroad industry economic regulator since then.

The STB has a broad economic, regulatory oversight of freight railroad companies. It resolves rate and service disputes, oversees carrier mergers and interchange of traffic among carriers. After rate deregulation, STB established a process to protect "captive" shippers from unreasonably high rates, a process that is often called a "rate-relief" process. Captive shippers are the shippers served by only one railroad with no competitive shipping alternatives.

Commodities that can be easily shipped by other modes of transportation, such as a barge or a truck, were later exempted from STB's jurisdiction. The primary reason for the exemption was that these commodities are unlikely to be captive. These are the commodities that could be shipped by boxcar or intermodal containers. According to a Department of Agriculture report, these exemptions, in addition to contracts, effectively freed about 75 to 85 percent of freight traffic from economic regulation by STB. Currently, the most frequently transported commodities that could be subject to STB rate regulation, by tons shipped, are grains and feed, assorted food items, coal, chemicals, and nonmetallic minerals.

Freight railroads can set rates through tariffs or contracts. Contracts are confidential agreements between the railroad and a shipper, and contain mutually agreed upon rates for specific routes and other service terms for a specific shipper. Contracts are usually shipper specific and confidential, while tariffs are set for a given route and can be relatively simply found on major company's websites. Upon request, railroads are required to offer tariff rates to any shipper. STB only has the authority to review the tariff rates.

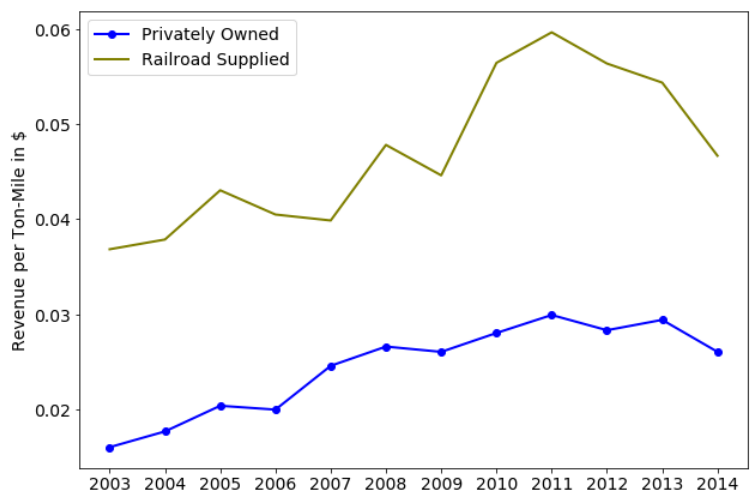
The STB resolves disputes regarding the rates or terms in a tariff under rate-relief process. It can only review the rates that were not set under the contract, and the commodity in question is not exempt from rate regulation, and the railroad has a "market dominance." FIt should be proven that the rate exceeds 180 percent of the railroad's variable cost using pre-established cost calculation routine; and that no potential competition from railroads or other modes of transportation exists.

In the cases when the rate was shown to be unreasonable, STB may intervene and order the railroad to pay reparations to the shipper. According to United States Government Accountability Office (2016) (GAO), between 1996 and 2016, STB reviewed 50 rate reasonableness cases. 32 out of 50 cases were for shipments of coal, and 16 for chemicals. About half of the cases were settled before STB intervention, and 11 cases were decided in favor of shippers by STB, and 10 in favor of railroads.

GAO interviewed representatives of the four largest Class I railroads and found that railroads similarly set both rates and tariffs. They examine market factors, such as competition from other forms of transportation, i.e., truck, barge, competition from other railroads, and how much shippers are willing to pay. Both tariffs and rates are usually specific to a commodity group and geographic market. GAO found that the contracts are usually no longer than 1 to 5 years, and typically include periodic rate adjustments.

Previous literature (MacDonald (1987), Eakin et al. (2008)) highlighted that characteristics such as car ownership, length of haul and number of carloads might influence freight railroad rates. To show this, I present revenue per ton-miles trends for coal and grains and feeds commodity groups.

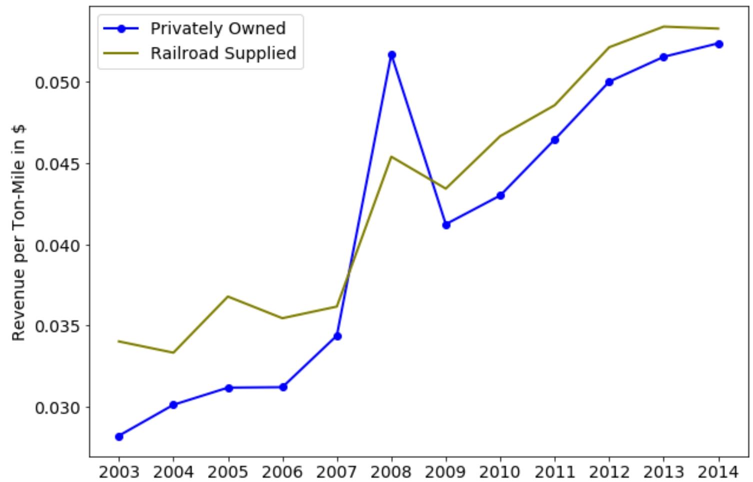
Figure 1.34: Coal Rates by Car Ownership, 2003-2014



Source: STB Carload Waybill Sample

A shipper can own a freight car or lease it from a railroad company. Private cars are those that are not directly owned by the railroad company and include cars owned by shippers or leased by shippers from independent car companies. Private car ownership in coal commodity group has been growing significantly over the years from about 27% in 2003 to 67% in 2014. However,

Figure 1.35: Grains and Feeds Rates by Car Ownership, 2003-2014

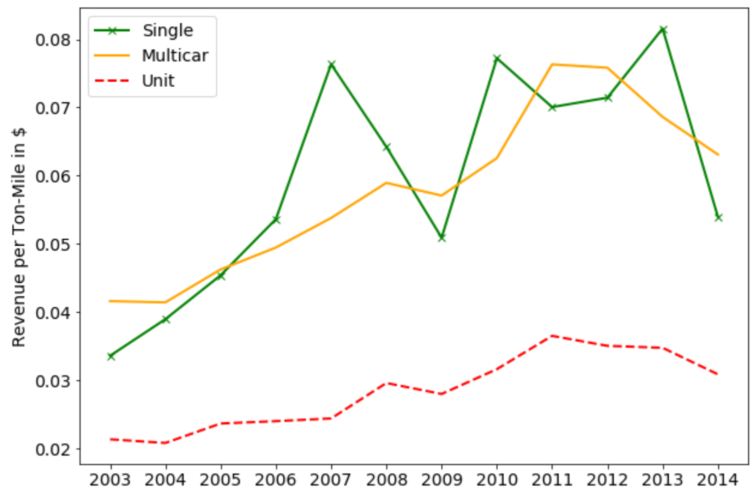


Source: STB Carload Waybill Sample

it dropped in grains and feed from 40% to 30%. Figures 1.34 and 1.35 show the trend in rates for the two commodity groups. Using a privately owned car to ships goods in both commodity groups results in a lower rate on average. However, the discount is much higher for coal. The average price of a shipment in a private car was almost twice as cheap as in a railroad supplied the car. This result should be considered with caution, as private car ownership may be correlated with other factors that influence the price, for example, the number of cars in a waybill.

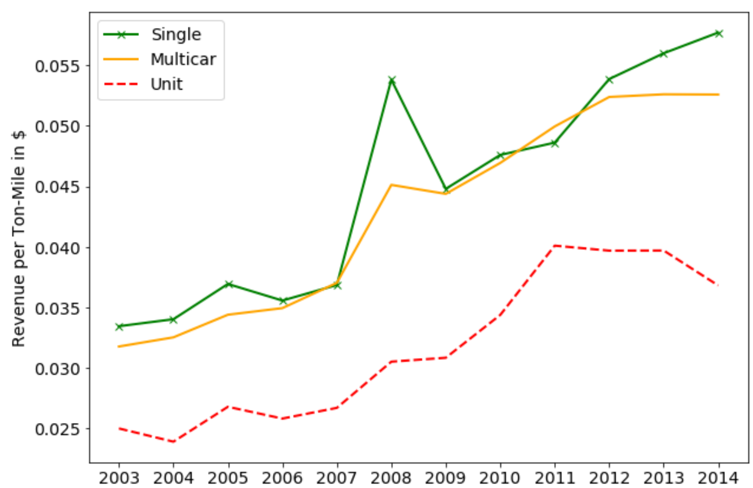
Moving many cars on the same train from a single commodity to a single destination without a need to rearrange the cars helps railroad companies reduce the cost of the haul. In turn, railroad companies provide a discount to the shippers that can aggregate the shipments into unit trains. The use of

Figure 1.36: Coal Rates by Number of Carloads, 2003-2014



Source: STB Carload Waybill Sample

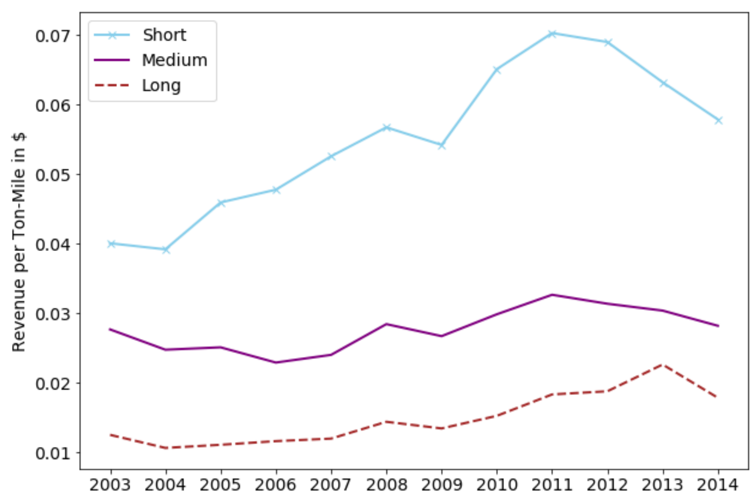
Figure 1.37: Grains and Feeds Rates by Number of Carloads, 2003-2014



Source: STB Carload Waybill Sample

unit trains has been steadily increasing over the years. The share of waybills with over 50 carloads of grains and feed in 2003 was 13%, while it increased to 16% in 2014. Coal has seen an even more rapid increase. In 2003 only about 21% of waybills had over 50 carloads, while in 2014 almost 90% of freight was moved this way. Figures 1.36 and 1.37 show the trend in rates for the two commodity groups. Single indicates waybills with less than five carloads; multicar indicates waybills with 5-49 cars, and unit indicate waybills with 50 carloads and more. The rate difference between single and multicar waybills is not significant, while unit trains seem to provide quantity discounts in both coal and grains and feed commodity groups.

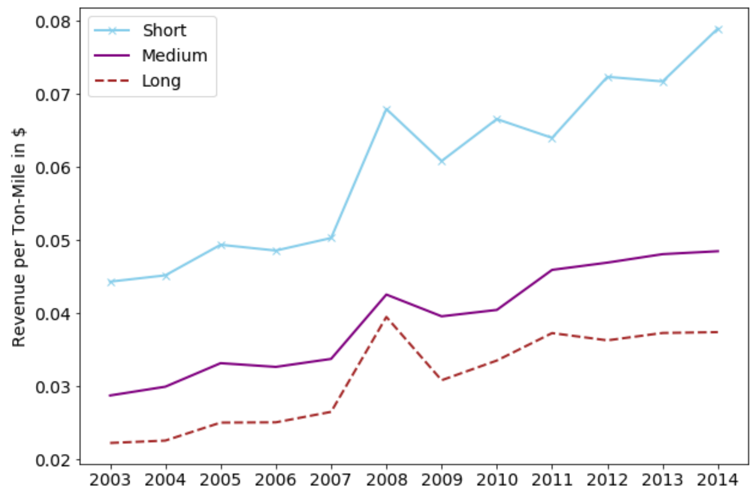
Figure 1.38: Coal Rates by Distance, 2003-2014



Source: STB Carload Waybill Sample

The third shipment characteristic of interest is distance. Due to the economies of scale, and costly loading and unloading, it is usually cheaper to

Figure 1.39: Grains and Feeds Rates by Distance, 2003-2014



Source: STB Carload Waybill Sample

ship freight on longer distances. Figures 1.38 and 1.39 show the trend in rates for the two commodity groups. Short indicates all shipments for the distance less than 500 miles, medium - 500 miles to 1000 miles, long - over 1000 mile. It is clear that for both commodity groups rates on longer-distance shipments are on average lower per ton-mile than rates on shorter-distance shipments.

1.5 Conclusion

In this chapter, I have provided a broad overview of the U.S. freight railroad industry, discussed major railroad companies, dynamics in the commodity markets, and the rate-setting process. It is essential to understand the heterogeneity of the commodities that are shipped by freight railroads to be able to conduct a proper economic analysis in the following chapters. There have been major structural exogenous shifts in the demand for freight railroad services from 2003 to 2014. Intermodal, automotive products, metals and minerals, and construction and forest products commodity groups have seen a decline in the ton-miles of freight originated in 2009 due to economic crises. Some of them have fully recovered since the recession; some are still on a recovery path. Coal shipments have declined due to the Clean Air Act; coal production has also shifted from Appalachia region to Powder River Basin due to regulations limiting sulfur dioxide emissions. Energy products and fuels commodity group has been profoundly affected by the shale oil boom. Shipments of oil by train doubled from 2010 to 2014. These exogenous shocks to the demand will be highly useful in the identification of structural models of the following chapters.

Chapter 2

Tragedy of the Anticommons in Complementary-Good Markets

2.1 Introduction

There were 33 class I railroads in the 1980s, and there are only seven today. This process of consolidation came to at least a temporary end at the turn of the 21st century. The consolidation stopped when the Surface Transportation Board (STB), the regulator in the freight railroad industry, faced with the first proposal to form a transcontinental railroad in the U.S., the proposed end-to-end merger of BNSF with CN. STB first imposed a temporary freeze on Class I rail mergers, and then issued new merger guidelines that significantly increased the burden of proof on merging parties to demonstrate that the merger would be in public interest.

As of today, there is no single transcontinental railroad company, and a shipper that needs to move goods from the east coast to the west coast would have to use the services of multiple railroads, and therefore, purchase perfect complements. It had been recognized more than 150 years ago by Ellet (1839) that when segments of road or railway are owned by independent companies, it creates a complementary oligopoly.

The effects of such a market structure were first studied by Cournot (1838). He showed that both profit and efficiency are higher under integrated monopoly than a complimentary oligopoly. Later, the welfare effect of complementary monopoly has been analyzed by a number of researchers including Economides et al. (1991) who extend the Cournot complementary monopoly to a duopolistic setting. Theoretical literature and models continued to develop, with research by Lemley and Shapiro (2006), Lerner and Tirole (2015), Rey and Salant (2012), and others trying to unpack the effects of the "tragedy of anticommons" and analyze if firms can reach Pareto improvement in setting rates without intervention by a regulator. The analysis has been extended to the literature on double marginalization, royalty stacking in intellectual property literature, patents, and others. See, for example, Heller (1998), Heller and Eisenberg (1998), and Buchanan and Yoon (2000), with most of the work being specifically about patents.

A number of studies evaluate the welfare effect of airline alliances[1]. Early research indicated that fairs in interlined markets fall due to the ease of cooperation and elimination of double marginalization. However, multiple studies find that code-sharing can lead to increased prices on non-stop parallel routes. Armantier and Richard (2006), Gilo and Simonelli (2014) find that fares are significantly higher on nonstop code-shared flights as compared to

[1] Bilotkach and Hüschelrath (2011), Bilotkach and Hüschelrath (2013), Oum et al. (1996), Park (1997), Brueckner (2001), Brueckner and Whalen (2000), Heimer and Shy (2006), Bilotkach (2005), Bilotkach (2007b), Bilotkach (2007a), Barla and Constantatos (2006), Chen and Gayle (2007), Flores-Fillol and Moner-Colonques (2007)

the flights offered by non-allied companies. Gilo and Simonelli suggest that because codesharing airlines can more easily coordinate in setting fares and have more opportunity to punish the party deviating from collusive agreement, alliances may ease collusion in all the markets that they serve together. This will benefits interline passengers, but would harm those traveling on routes where airlines compete.

Freight railroads own the infrastructure they operate on, including tracks, and therefore, most of the time, the owner of the tracks is the sole operator on the line. There are two geographical duopolies, one in the East and one in the West, and a couple of other companies that offer routes in the northern part of the U.S. and Canada, along Mississippi River, and in the South and Mexico. No merger proposal has been submitted to the freight railroad industry regulator since the 2000s. However, some of the railroad industry experts are convinced that the industry will become even more consolidated. Hunter Harrison, a former CEO of Canadian Pacific Railway, stated that the "final round of mergers is not a question of if, but when." While Linda Morgan, the head of the Surface Transportation Board in 2000, wrote that "While mergers have their place, recent events have shown that no major merger takes place in isolation, and that, once a round of mergers begins, it can be all-consuming, distracting, and disruptive, to the detriment of the nation's transportation system, rail shippers, rail employees, and communities across the country." Therefore, it is essential to understand the welfare implications of this consolidation, and which mergers should be allowed by the regulator and which blocked.

In 2016 CP submitted a bid to acquire NS. The combined network would connect Vancouver, B.C., and the East and Gulf coasts of the United States, enhancing options around the gridlock of Chicago and potentially removing inefficiency from the pricing of complements. The proposal faced a wall of opposition. STB has received dozens of letters from shippers, lawmakers, and other railroads. Union Pacific Railroad CEO Lance Fritz called blocking the deal "job 1" for his railway and the industry at large. Competing railroads may have the incentive to block the merger because they are afraid of vertical exclusion, or because it may result in more substantial head-to-head competition on the routes where CP and NS interline. The increase in competition happens because, by merging, complementary firms remove the negative pricing externality and become more aggressive competitors to the substitute firm.

The Journal of Commerce[2] analyzed more than 100 letters written to STB by industry participants after CP submitted a bid to acquire NS. They found that shippers of agriculture and metal products backed the potential tie-up, while UPS, FedEx, and other significant logistics players opposed the deal. Auto and energy product shippers were split. Letters cite several reasons why the merger would be in the public interest. They frequently refer to the issues of Chicago congestion, the opportunity to create reliable single-line service that

[2] Hutchins (2016)

runs from the west coast in Canada to the eastern U.S., improved customer service, and reducing highway congestion.

Remarks by BNSF and UP hint that CP-NS merger is likely to spell another round of consolidation. "We've never in this industry just done one merger," Matt Rose, BNSF executive chairman, said according to a Bloomberg report. "You do a merger and then somebody else announces it because of this issue of stabilization of the industry and parity in various markets."

The purpose of this chapter is to understand the welfare implications of the next round of consolidation in the freight railroad industry. By estimating a structural model of demand and supply in the industry, I am able to conduct merger simulations between different pairs of railroads; find a scenario that results in the highest welfare; understand who gains and looses the most: shippers, merging parties, or outsiders; and decompose the effects on consumers by commodity.

In recent years, a considerable amount of interest on the part of the Antitrust agencies in the U.S. and the EU has been devoted non-horizontal mergers. Both U.S. and EU agencies have established guidelines for non-horizontal mergers where they distinguish two broad types of mergers: vertical and conglomerate. It has been the norm in the U.S. to use the tools of vertical mergers to evaluate complementary product mergers[3], while EU treats mergers involving suppliers of complementary products as conglomerate mergers. Although

[3]For example, Northrop Grumman/TRW, GE/Avio, and Live Nation/TicketMaster each could be characterized as complementary product mergers.

antitrust laws are phrased differently in the two regions, and sometimes have conflicting opinions on merger proposals[4], antitrust laws in the U.S. and across the Atlantic generally pursue the same objectives.

Antitrust agencies have long recognized removal of double - marginalization or internalization of pricing inefficiency in case of complementary goods mergers. For example, Verizon/MCI and SBC/AT&T mergers were approved by the Department of Justice in 2005. The pairs of firms were engaged in complementary activities: long distance and local telecommunication services. A significant factor in DOJ's decision not to challenge the proposed mergers was that the mergers were likely to produce substantial efficiencies. The merging long distance carriers (AT&T and MCI) have generally relied on local carriers (SBC and Verizon) for customer access. The merger allowed these firms to provide the products at a lower cost to the consumers by internalizing pricing inefficiency.

Antitrust authorities understand that vertical integration and conglomerate merger can solve the problem of inefficient pricing of complements and benefit consumers. However, they also recognize other factors should be taken into account. For example, the in Comcast/NBCU competitive impact statement DOJ concluded: "much, if not all, of any potential double marginalization is reduced, if not completely eliminated, through the course of contract negotiations." Both U.S. and EU antitrust agencies have considered other po-

[4]GE and Honeywell proposed to merge in 2000, the firms were producing complements. The deal was approved in the U.S., but was blocked by the EU Competition Directorate.

tential effects such as foreclosure, tying and bundling, and entry deterrence. Another substantial anticompetitive effect of a merger is that, with fewer players on the market, the probability of collusion between them increases. This dissertation will address this aspect in the next chapter.

The remainder of this chapter is structured as follows. Section 2 provides a theoretical background of complementary monopoly. Section 3 defines markets and describes primary data sources used in the analysis. Section 4 provides a brief reduced form analysis as evidence of double marginalization in the freight railroad industry. The structural model is estimated in section 5, and merger simulations as a part of the counterfactual analysis is performed in section 6. Section 7 concludes.

2.2 Theoretical Background

2.2.1 Complementary Monopoly

A complementary monopoly refers to a market setting where a different monopolist produces each of the complementary goods. These goods are only demanded in bundles, at equal quantities, and there is no demand for each good by itself. This model was first studied in Cournot (1838)[5]. He showed that both profit and efficiency are higher under integrated monopoly, where a single firm offers complements forming a composite good than under a complementary monopoly. This is often referred to as the "tragedy of the

[5]Sonnenschein (1968) formalized Cournot's arguments and showed that Cournot duopoly is the dual of this complementary monopoly.

anticommons" or "double-marginalization." In his discussion vertical and complementary monopoly, Tirole (1988), states, "What is worse than a monopoly? A chain of monopolies."[6]

In the setting of complementary monopoly, consumers only care about the combined price of a bundle, which makes demands for the complements interrelated. A firm producing a single good takes into account only the impact of a price rise on its own profits, without considering the negative externality imposed on the sellers of other complementary goods. Each seller earns the full benefit of an increase in the price of his good but bears only part of the cost associated with a reduction in the quantity demanded due to the price increase. The externality problem generates a prisoners' dilemma among the suppliers of complementary goods. As a result, prices will be higher with separate producers than with an integrated monopolist, generating a lower consumer surplus and profits.

To better understand the nature of this inefficiency, consider a simple textbook example from Pepall et al. (2014). There are two goods that are perfect complements, i.e., consuming one without another gives zero utility. Suppose that the demand function for the composite good is

$$Q = A - (P_1 + P_2) \tag{2.1}$$

[6]While he refers specifically to a vertical arrangement where one monopolist controls an input to be sold to another monopolist for use in the production of a final good, he points out that the statement is also true for two monopolists producing complementary goods to be consumed in fixed proportions.

where P_1 is the price of good 1, and P_2 is the price of good 2. Equation 3.1 represents separate demands that each monopolist faces because consumers only buy two goods together. Therefore, $Q_1 = Q_2 = Q$. The change in the price of a good one not only changes the quantity demanded of a good one but also of good two. This implies that each firm's pricing decision has profit implications for both firms.

Let the marginal cost of production of good 1 and 2 be c_1 and c_2 respectively. Each firm chooses price to maximize their profit

$$\max_{P_i}(P_i - c_i)(A - P_i - P_j) \quad \forall i \in \{1,2\},\ j \neq i \tag{2.2}$$

Maximization yields

$$P_i = \frac{A + c_i - P_j}{2} \tag{2.3}$$

Jointly solving for both goods yields equilibrium prices:

$$P_i = \frac{A + 2c_i - c_j}{3} \tag{2.4}$$

And the price of composite good is

$$P^0 = P_1 + P_2 = \frac{2A + c_1 + c_2}{3} \tag{2.5}$$

From the demand equation 3.1, the number of units of composite good consumed is

$$Q^0 = \frac{A - c_1 - c_2}{3} \tag{2.6}$$

The combined profit of both firms is

$$\pi^0 = \pi_1 + \pi_2 = \frac{2}{9}(A - c_1 - c_2)^2 \tag{2.7}$$

The consumer surplus is

$$CS^0 = \frac{1}{18}(A - c_1 - c_2)^2 \tag{2.8}$$

Now consider a situation when the two firms merge and the newly combined firm sells a bundled product (combination of goods 1 and 2). Such a firm faces the joint demand curve 3.1 and recognizes that the relevant price to consumers is the combined price of two goods. Because goods are only consumed in one-to-one ratio, there is no point of selling goods independently. The prices of individual components of the bundle are non identifiable. The marginal cost of producing the bundled good is $c_1 + c_2$. The firm's objective function is

$$\max_P (P - c_1 - c_2)(A - P) \tag{2.9}$$

This yields

$$P^1 = \frac{A + c_1 + c_2}{2} \tag{2.10}$$

Substituting price back to the demand equation

$$Q^1 = \frac{A - c_1 - c_2}{2} \tag{2.11}$$

And the firm's profit is

$$\pi^1 = \frac{1}{4}(A - c_1 - c_2)^2 \tag{2.12}$$

The consumer surplus is

$$CS^1 = \frac{1}{8}(A - c_1 - c_2)^2 \tag{2.13}$$

Table 2.1: Effects of Merger in Complementary Monopoly

	Complementary Monopoly	Integrated Monopoly	Change
P	$\frac{1}{3}(2A + c_1 + c_2)$	$\frac{1}{2}(A + c_1 + c_2)$	$\frac{1}{2}(A - c_1 - c_2)$
Q	$\frac{1}{3}(A - c_1 - c_2)$	$\frac{1}{2}(A - c_1 - c_2)$	$-\frac{1}{6}(A - c_1 - c_2)$
π	$\frac{2}{9}(A - c_1 - c_2)^2$	$\frac{1}{4}(A - c_1 - c_2)^2$	$-\frac{1}{36}(A - c_1 - c_2)^2$
CS	$\frac{1}{18}(A - c_1 - c_2)^2$	$\frac{1}{8}(A - c_1 - c_2)^2$	$-\frac{5}{72}(A - c_1 - c_2)^2$

Table 2.1 provides a comparison of combined price, quantity, profits and customer surplus for the two cases. The comparison reveals that the merger of the two firms leads to lower prices and higher quantity consumed. This is because the merged firm understands the interaction of demand between the two products. As a result of this coordination, consumers are made better off — the consumer surplus increases due to the price reduction. Additionally, the combined profit is higher in the case of monopoly; this is because independent firms price inefficiently high. This was Cournot's main point, by internalizing the interdependence of demand for two goods, the firms can remove inefficiency from pricing complements, and as a result, both consumers and producers gain. Though it should be noted that this is a second-best result. The combined price exceeds the optimal price that is equal to the marginal cost.

A merger is not the only way to achieve efficiency gains in complementary monopoly markets. Other forms of coordination can be established to take better account of the interactions between demands for complementary goods. For example, airline codesharing agreements [7] (Brueckner and Whalen (2000), Brueckner (2003), Ito and Lee (2005)), alliances in supply chains (Stallkamp (2001) discusses alliances formations among auto part suppliers, patent pooling (Shapiro (2001), Lampe and Moser (2010)). Moreover, firms do not necessarily have to form formal agreements. If firms are repeatedly interacting, they may be able to sustain tacit collusion and remove negative externality from double marginalization.

2.2.2 Competition within Complementary Goods

The section above describes negative externality that arises from pricing perfect complements and how a coordinated price setting or merger can eliminate it. It primarily relies on the assumption of monopoly in complements' markets. However, if the competition is introduced, the results may not hold any longer. Dari-Mattiacci and Parisi (2006) investigate the impact of competition on welfare in complementary goods markets. They find that two substitutes per component are sufficient to reach welfare improvements equivalent to the ones of a merger when firms choose to price a la Bertrand. However, when firms choose the quantity, the availability of substitutes, regardless of their number, is ineffective.

Assume that there are multiple producers of good 1 that produce ho-

[7] Codesharing is a contractual agreement among airlines under which the "ticketing carrier" is allowed to market and sell seats on its partner's flights.

mogeneous goods. In this case, the price in market 1 would fall to marginal cost. Each firm there would be so small that it would not be able to impose any external effects on the monopoly of market 2. Plugging $P_1 = c_1$ into best response equation 2.3 for firm 2, yields $P_2 = (A + c_2 - c_1)/2$. In this setting, the seller of good 2 can extract higher rents. Although the price of good 2 is higher, the total combined price of two goods is equal to the price under monopoly, $P = (A + c_1 + c_2)/2$. Therefore, the welfare implications of adding competition in one of the complementary goods markets result in the same welfare effects as a merger. If both markets were to become competitive, then both good 1 and 2 would be priced at marginal cost. This would result in the highest welfare, and all the surplus would be attributed to the consumers, firms would collect zero profits.

Economides et al. (1991) compare equilibrium prices and welfare effects under different ownership when two differentiated brands of each of two components of a good are offered. They contrast joint, parallel, and independent ownership. Under joint ownership, a single firm produces all components. The authors assume that under parallel vertical integration price discrimination or vertical exclusion is not allowed; thus consumers that purchase both components from the same firm cannot be favored. They find that prices are always lower in parallel vertical integration than in independent ownership. However, the welfare effect of full integration is ambiguous. The prices are lower under the joint ownership than parallel vertical integration when two composite goods are highly differentiated. If goods are moderate substitutes, prices are higher under full integration than under parallel vertical integration but lower than under independent ownership. For very close substitutes, full integration results in a price even higher than independent ownership.

Quint (2014) considers a model of imperfect competition with heterogeneous preferences. In the model, three coal mines supply coal to a city. Each mine is connected to the city by an independent railroad. Buyers can choose to purchase coal from any of the three coal mines or be without coal. The buyer that chooses to purchase coal pays the price of coal to the mine and the cost of transport to the railroad. The author models demand for coal using a discrete choice model with heterogeneous preferences. He derives sufficient conditions under which a merger between a mine and a railroad serving the mine would lead to lower equilibrium prices, while a merger between two of the railroads would lead to higher prices for everyone.

Another interesting market setting was considered by Anderson et al. (2010). They present a model under which mergers increase consumer surplus, and decrease profits of non-merging firms in the market. In this model of airline competition, the passengers can travel from point A to point B using either a direct flight with airline 0 or a flight with one stop on airlines 1 and 2. Authors show that a merger between airline 1 and 2 always harms airline 0, and benefits consumers. This is because by merging, firms selling complementary products entirely internalize the inefficiency and reduce the price of the interlined flight. As a result, competing firm faces a more aggressive competitor and has to decrease its markups.

To sum up, the theoretical literature on complementary goods pricing has been vast, highlighting the negative externality that arises from demand interdependence. The most common way proposed in the literature to correct for this inefficiency is the internalization of demand interdependence with the help of merger, alliance, or other cooperative agreements. Researchers analyzed multiple market structures and found that the welfare effects of mergers can be ambiguous, especially if they decrease competition among substitutes. Vertical mergers among producers of complementary goods are usually associated with increased consumer surplus and welfare, while, under some market structure, firms' profit would decrease due to the merger.

2.3 Industry Overview

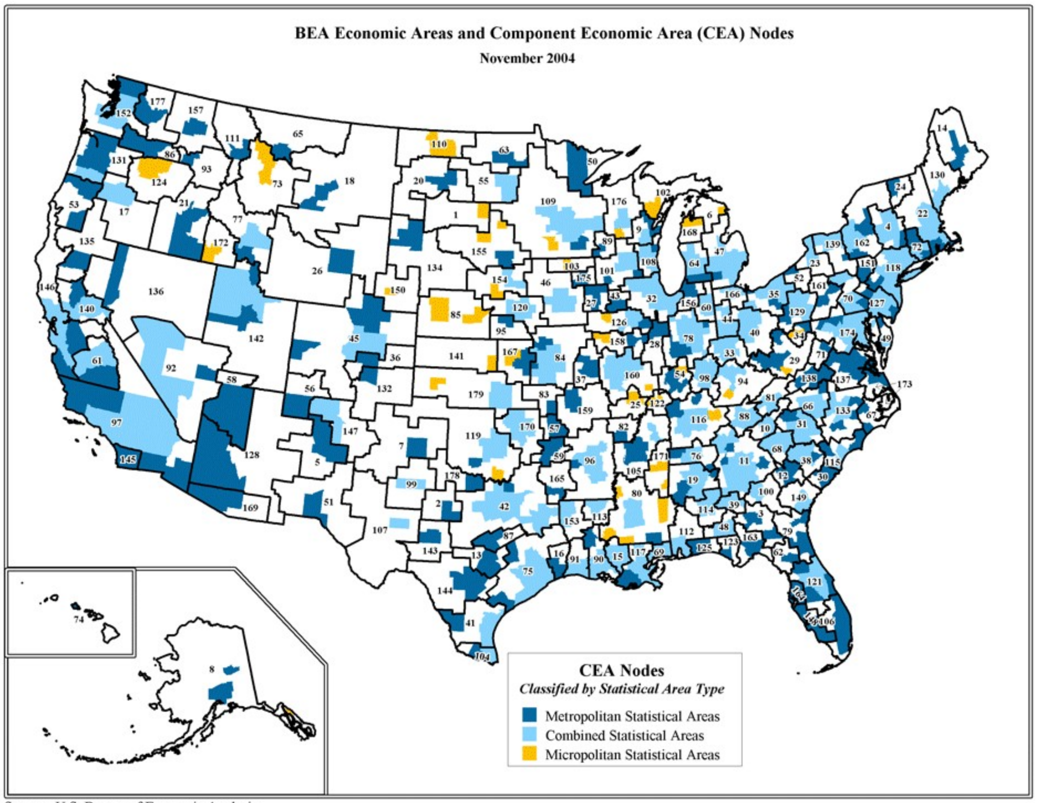
2.3.1 Market Definition

The starting point of conducting competitive analysis is the definition of relevant markets. Railroads' product is the transportation of goods between specific origin-destination pairs. Therefore, to define the markets one needs to choose a scope of geographic areas for origin-destination pairs as well as relevant commodity groups.

I define a market as a unidirectional movement of freight between origin and destination Bureau of Economic Analysis (BEA) Economic Areas in a particular year for a given commodity group. Each BEA area consists of a center node - Component Economic Area (metropolitan, combined or micropolitan statistical area) and the surrounding counties that are economically related to it. The BEA areas cover the entire United States. Figure 2.1 shows BEA areas on the U.S. map. The rationale for using broader geographic areas as origin and destination points is that shipper can benefit from the presence of a competing railroad even if it does not serve the shipper's exact location, for example, shippers can employ truck transloading to access a railroad. A customer can in some cases threaten to or actually build out a rail spur to access an alternative rail carrier. Further details and examples can be found in Grimm and Plaistow (1999). Additionally, BEA-BEA market definition follows that of the Justice Department in the Santa Fe - Southern Pacific and Union Pacific - Southern Pacific merger cases, and Pittman (1990).

I group commodities into nine commodity groups. The goods were grouped based on the Standard Transportation Commodity Codes (STCC) and equipment required to move the goods. These groups roughly correspond to major railroads' lines of business. Freight in different groups is likely to be shipped by very different customers that are unlikely to have identical price sensitivity, and railroads may possess a different degree of market power across the groups. Requiring different equipment to transport and load the goods means that the cost structure is different as well. See section 1.3 for more details about commodity groups. Table 2.2 lists the commodity groups, their description, the share of revenue, tonnage and ton-miles in 2014 CWS, and most common car types used to transport the goods in the group. The included commodity groups represent nearly 98 percent of tonnage, ton-miles, and revenue in the 2014 CWS.

Figure 2.1: BEA Economic Areas



Source: U.S. Bureau of Economic Analysis

In terms of tons originated, coal represents the most significant proportion of railroad shipments, about 40%. Chemicals, metals and minerals, and intermodal shipments (containers and truck trailers) are also relatively large categories in terms of tons originated. Examining the proportions of railroad revenues by commodity group, coal is now the second largest category, reflecting its low-value bulk commodity status. The intermodal shipments category represented only 11% of 2014 tons originated but accounted for 25.7% of railroad revenues. This is a consequence of the high value of intermodal railroad

Table 2.2: Commodity Groups Used to Define Markets

Commodity Group	**Share of Revenue (2014)**	**Share of Tonnage (2014)**	**Share of Ton-Miles (2014)**	**Car Types**
Automotive Products	7.8%	1.9%	2.0%	Flat Cars
Chemicals, Fertilizer & Plastics	13.3%	11.1%	11.2%	Hopper and Tank
Coal	22.2%	41.4%	40.0%	Gondola and Hopper
Construction & Forest Products	2.9%	2.3%	2.3%	Box and Flat
Energy Products & Fuels	4.0%	3.2%	3.7%	Tanks Cars
Food & Beverages	6.3%	5.3%	5.8%	Hopper and Tank
Grains & Feed	6.8%	6.5%	7.8%	Hopper Cars
Metals & Minerals	10.3%	16.3%	8.2%	Box, Gondola, Hopper, Flat
Intermodal	25.7%	11.0%	18.4%	TOFC/COFC

services.

2.3.2 Data description

STB Carload Waybill Sample

The primary source of data is unmasked confidential STB Carload Waybill Sample (CWS) for the years 2003 through 2014. The sample is a collection of railroad waybill records submitted to the STB by rail carriers that terminate 4,500 or more revenue carloads annually. It is roughly a 3% stratified sample of shipment level observations which is then expanded to represent 100% of all rail traffic. The sample includes information about the origin and destination of shipment, distance of haul, goods transported, their weight, railroads participating in the movement, revenue collected etc[8]. The main advantage of the unmasked CWS is that it provides actual revenue data reflecting tariff or contract rates at the level of shipment, which is unavailable from other sources of railroad operating statistics.

I screen the data to remove anomalous observations and outliers. I only keep shipments originating and terminating outside of 48 contiguous U.S. states. I exclude waybills with unusually heavy and light average tons per car, very high numbers of carloads on the waybill, very short shipment distances, and zero revenue. Most of the U.S. freight railroad systems are approved for the heavy axle rail cars that can handle up to 315,000 lbs. gross weight, therefore, I trim maximum tons per car at 315,000 lbs. I exclude waybills with more than 150 carloads, the maximum number of carloads in a unit train according to the guidelines of the major railroads. I also exclude observations with the distance under 100 miles. To estimate the structural model, I select

[8] A small percentage of interlined traffic in CWS was rebilled: reported as two separate shipments. These shipments were linked back together using a procedure described in the Appendix.

markets with at least 1500 carloads a year. CWS lacks meaningful micro-level data and does not include information about the shippers or receivers of the freight. I, therefore, aggregate it to a product level data set. I define a product as a shipment of goods in a commodity group by a railroad or a combination of railroads. All other characteristics of the product are averaged over the shipments. I drop products that do not represent competitive presence in the market and carry less than 2% of the market railroad tonnage.

Table 2.3 presents sample sizes, number of geographic markets, the average number of products per market and selected descriptive statistics by commodity group.

Table 2.3: Sample Size and Summary Statistics by Commodity Group

Commodity Group	Num. of Observ.	Num. of Geogr. Markets	Mean RTM*	Mean Tons	Mean Tons/Car	Mean Carloads	Mean Distance	Interline Share
Automotive Products	4575	283	0.16	23.24	22.34	1.01	968.19	0.15
Chemicals, Fertilizer & Plastic	8938	283	0.06	234.73	92.02	2.46	927.77	0.49
Coal	4028	240	0.03	10762.20	107.63	94.97	729.40	0.28
Construction & Forest Products	3843	132	0.06	83.84	79.14	1.06	931.01	0.48
Energy Products & Fuels	1433	74	0.07	702.39	78.05	9.04	770.33	0.42
Food & Beverages	5843	242	0.04	232.33	88.90	2.46	1091.57	0.26
Grains & Feed	5022	262	0.04	4463.87	101.66	42.72	326.91	0.21
Metals & Minerals	7817	344	0.06	871.19	95.27	8.55	5643.47	0.42
Intermodal	10180	576	0.07	14.15	13.16	1.01	1392.8	0.24

* Revenue per ton-mile in 2009 Quarter 1 dollars.

Freight Analysis Framework

I use Freight Analysis Framework (FAF) database version 4 to estimate market size - tons of freight of a given commodity hauled between origin and destination BEA areas. FAF is produced jointly by the Bureau of Transportation Statistics and Federal Highway Administration. It integrates data from a variety of sources to create a comprehensive picture of freight movement among major metropolitan areas by all modes of transportation. Railroads compete with trucks, barges, and pipelines to transport commodities and finished goods. Due to the nature of goods and volumes that are handled, the main competitors for rail in the domestic freight segment are trucks and to a lesser extent, barges and pipeline. As railroads are more fuel efficient, demand is also driven by fuel prices. High gas prices shift freight transport from truck to rail. Between 2011 and 2012, a period of rising gasoline prices, ton-miles carried by trucks dropped by about 30%, while ton-miles carried by rail did not change significantly (see figure 2.2).

Figure 2.3 provides a share of each mode of transportation by commodity group for the entire United States in 2014, and figure 2.4 shows modal shares by the distance of haul. The share of rail in the total freight flow varies with the commodity group and distance. Speed and flexibility give truckers an advantage on short routes, while rails have the upper hand on long hauls and carrying bulk freight, such as coal.

Additionally, I use the National Transportation Atlas Database published by Bureau of Transportation Statistics, and R-1 Railroad Annual Re-

Figure 2.2: U.S total ton-miles of freight by mode (in Billions)

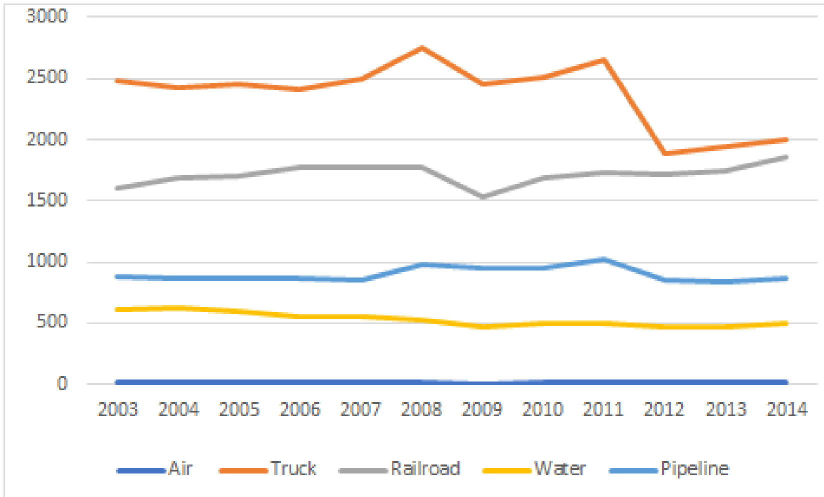
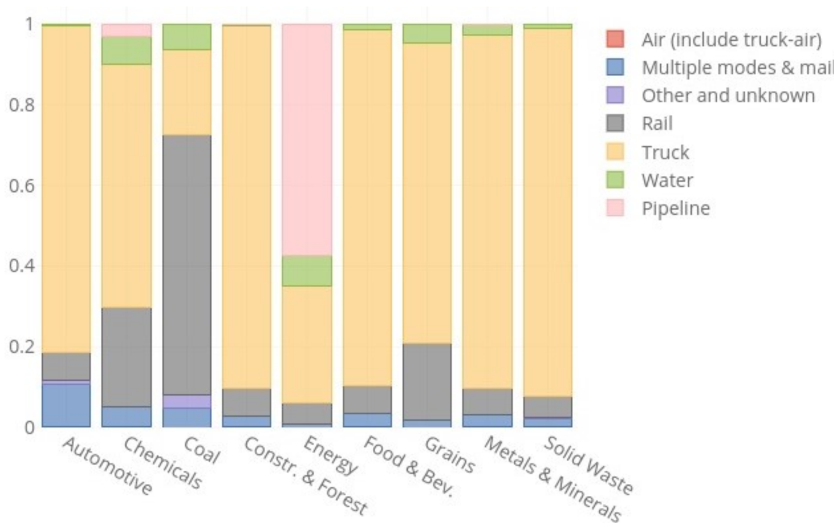
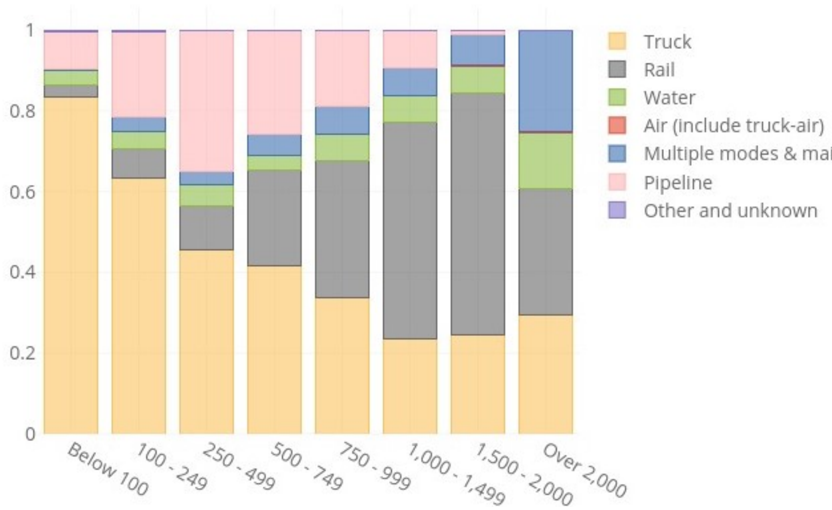


Figure 2.3: Modal Share by Commodity Group in 2014



ports from Financial & Statistical Reports published by Surface Transportation Board to construct instrumental variables, which are discussed later. I also use Statistics of U.S. Businesses to proxy for shipper size in demand esti-

Figure 2.4: Modal Share by Distance in Miles in 2014



mation of the structural model.

2.3.3 Analysis of Revenue Over Variable Cost

When STB resolves disputes regarding freight tariffs it analyses the ratio of rate to the variable cost of providing the service, it is called revenue-to-variable cost ratio (RVC). A rate higher than 180% of RVC is subject to a potential STB review, given other conditions hold (for more details see section 1.4). RVC is calculated using the variable cost measure derived from the Uniform Rail Costing System (URCS). URCS was adopted in 1989, and it utilizes a mix of accounting and statistical procedures to estimate the cost of a particular shipment. URCS inputs reported cost information into a computer program to provide estimates of the variable cost based on observable cost characteristics. According to Rhodes and Westbrook (1986) "In the URCS, variable costs for specific freight movements are calculated as weighted averages of total costs from individual cost categories that comport with cost categories defined in railroad accounting practices" (p. 290). For more detailed description of URCS see Rhodes and Westbrook (1986), Wilson and Bitzan (2003), Wilson and Wolak (2016).

URCS and measure of RVC have been criticized by recent research in the field for not representing a cost measure that a profit-maximizing firm would use to set the price. Wilson and Wolak (2016) note that "URCS is a methodology for allocating rail costs to individual shipments rather than a method for measuring the increase in the railroad's costs caused by a shipment." While this criticism is fair, I believe that RVC can serve as a good measure for descriptive evidence of differences in markups across the markets. The measure of variable cost from URCS would account for observable market differences, like products shipped, distance, geography, and allow us to compare "markups" across the markets. I put quotes around markups because RVC does not represent the true markups that are measured using marginal cost.

Table 2.4: Revenue-to-Variable Cost Ratio by Origin and Termination Railroad in 2003

	BNSF		UP		CSXT		NS	
BNSF	1.325		1.946	2.040	2.143	1.869	1.867	1.408
UP	2.102	1.940	1.481		2.097	1.636	2.244	1.767
CSXT	1.543	1.891	1.680	1.633	1.415		1.918	2.268
NS	1.266	1.515	1.567	1.771	2.192	1.854	1.171	

Table 2.4 provides average RVC by origin and termination railroad for the four largest railroads in 2003. Here row indicates the origin and column termination. Left input is RVC of originating railroad, right is of terminating. For example, in the waybills where BNSF originates the freight movement, and CSXT terminates, RVC of BNSF is 2.143 and RVC of CSXT is 1.869. Notice, that for each railroad RVC is always smaller when there is no interline (same origin and termination railroad) than in the cases with an interline. This provides descriptive evidence of the inefficiency from the pricing of complements.

2.4 Reduced Form Analysis

One may argue that firms are sometimes able to form informal agreements to coordinate when setting prices of complements. After all, it is beneficial for them. The pricing game is an analog of prisoners' dilemma, and according to the "folk theorem," one can support cooperation in repeated prisoners' dilemma in infinitely-repeated games with sufficiently high discount factors.

To investigate whether data supports the hypothesis of the tragedy of anticommons that pricing of complementary goods is inefficient, I run a series of reduced form regressions. In particular, I am interested in whether the price in the markets where freight is interlined is higher than in the markets with no interline. In this exercise, I compare prices in monopolistic markets with and without an interline, and expect price in the latter group to be higher on average holding everything else fixed. I select only monopolistic markets to isolate the effect of competition from other railroads. As is described in section 2.2.2, competition within complements may sometimes have ambiguous effects on prices. While in the monopolistic markets, the effect of double marginalization must be most pronounced. The regression specification is as follows,

$$\ln RTM_{jmt} = \beta X_{jmt} + \gamma IL_{jmt} + \varepsilon_{jmt} \tag{2.14}$$

where RTM_{jmt} is revenue per ton-mile of product j in market m at time t, price measure traditionally used in transportation industry. RTM is equal to freight revenue divided by the weight of load times the distance of haul. IL_{jmt} is a dummy variable equal to one if the freight was interlined, i.e., if the product j is a composite of two complementary products. A positive value of γ would indicate that railroads were not able to internalize the inefficiency from pricing complements. X_{jmt} are control variables, including time and commodity group fixed effects, origin and termination BEA area dummies and origin and termination railroad dummies.

I follow MacDonald (1987) and other modern literature that studies rates in the U.S. freight railroad industry in my choice of control variables. They include two sets of controls, shipment cost characteristics and market structure indicators. Shipment cost characteristics comprise of the natural logarithm of length of haul, size of the load, tons per car, an indicator for private car ownership. I expect negative signs on the coefficients of these variables. MacDonald uses the volume of shipments between the origin and destination states as an indicator of the ability to form unit trains and to capture economies of scale, I refrain from including this variable into the analysis as it is likely to suffer from endogeneity problem.

As stated earlier, I only include monopoly markets in this exercise; therefore, direct competition from other railroads will not influence prices. However, railroads also compete with other modes of transportation, like truck and barge. Increasing the distances to port and waterway facilities would tend to reduce railroad pricing constraints from water transport, as the cost of accessing the alternative mode increases. This effects should be absorbed by origin and termination BEA area dummies[9].

Table 2.5 provides estimation results on data pooled for all commodity groups. Signs on all coefficients are consistent with the expectations. I find that increased length of haul, shipment weight, and weight per car are associated with the lower price paid. I also find that shippers pay a lower rate when using privately owned cars. As expected, IL variable has a positive and statistically significant coefficient. A route with an interline is 19.5% more expensive than a route without an interline holding everything else fixed. It should be noted that all 19.5% may not be attributed to double marginalization; there may be potential costs to interlining that make it more expensive

[9] I tried controlling for distance to the nearest port or waterway facility from origin and destination points as in MacDonald (1987), but the estimated coefficients on these variables were not statistically significant. The distance was calculated as great-circle distances between the origin/destination station zip code and zip code of nearest waterway facility using NBER ZIP Code Distance Database. Information about waterway facility zip codes was taken from U.S. Army Corps of Engineers Port and Waterway Facilities Navigation Data Canter.

Table 2.5: Effect of Interline on Revenue per Ton-Mile

	OLS
Constant	2.029***
	(0.091)
ln(Miles)	-0.438***
	(0.007)
ln(Tons)	-0.074***
	(0.004)
ln(Tons/Car)	-0.452***
	(0.021)
Private Car	-0.121***
	(0.010)
IL	0.195***
	(0.014)
R^2	0.795
N	10905

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

to ship freight on interlined routes. The above result is in line with previous literature. Schmidt (2001) analyzes data for 1992 and finds that interline shipment is more costly than single-line shipment. In particular, in monopoly markets, the prices are 14.4% higher with an interline.

2.5 Structural Model

2.5.1 Consumer Demand

I use a differentiated product model to estimate the demand for railroad freight transportation. In this model, the characteristic that most differentiates products from each other is the location of origin and destination stations and the duration of the haul, which translates into network structure of the railroad relative to other transportation infrastructure. In every market m at year t shipper $i = 1, ..., N_{mt}$ chooses logistic channel k to maximize its utility (minimize logistic cost of shipment) U_{ikmt}.

$$U_{ikmt} = x_{kmt}\beta + \alpha_i p_{kmt} + \xi_m + \xi_t + \xi_{kmt} + \varepsilon_{ikmt} \tag{2.15}$$

where x_{kmt} is a vector of observable logistic chain characteristics, p_{kmt} is the price, (β, α_i) are the taste parameters for consumer i; ξ_m and ξ_t are respectively market and year fixed effects, ξ_{kmt} - market specific taste for each logistic channel that is unobservable to the researcher but observable to and equally valued by all consumers, and ε_{ikmt} is an consumer-specific idiosyncratic term, iid draws from a Type I extreme value distribution.

Consumer preferences are assumed to depend on the valuations constant across individuals, demographic variables, D_i, and parameters Π that measure how preferences vary with demographics[10]. Therefore, preferences have the following distribution across the population:

$$\alpha_i = \alpha + \Pi D_i \tag{2.16}$$

I use a proxy for the size of the sipper i as a demographic variable. Intuitively, we would expect different price sensitivity and ability to substitute

[10] I also experimented with adding persistent preference heterogeneity in the form of classical normally distributed preference shocks. While these models led to elasticities that were similar to the demand specifications above, the standard errors increased; therefore I opted for a model with only demographic interactions.

to other providers depending on the size of the shipper. I use the number of payroll employees as a proxy for the shipper size for all commodity groups but grains and feed[11], and farm sales in thousands of dollars for grains and feed commodity group. I use Statistics of U.S. Businesses dataset to build an empirical distribution of firms by the log of the number of employees in every BEA for a given commodity group in every year. I then fit a Gamma distribution to the data and draw 1000 observations from the distribution. For grains and feed commodity group, I use data from the Census of Agriculture, which is only available for 2002, 2007 and 2012, and thus the distribution of sales by the farm is extrapolated to the missing years.

The observable characteristics x_{kmt} include a constant, origin and termination railroad dummy for class I railroads, an indicator of interline on the route, a total distance of haul, and traveled distance divided by the shortest road distance to capture the difference in time from shipment to delivery. The last variable can be relevant because railroads operate on fixed networks that differ from railroad to railroad. While one company may connect the origin and destination point with a straight line, another company may need to loop around. This can also be a deciding factor to shift to outside option. I define the price variable to be revenue per ton in a thousand dollars, in contrast to revenue per ton-mile in the reduced form analysis. The reason for this is that revenue per ton-mile metric will not be representative of a price when the length of haul is different due to the differences in network structure between

[11]Statistics of U.S. Businesses does not cover crop and animal production industries.

origin and destination points. A shipper cares about how much he would pay to move the freight from origin to destination, and not about the price per mile.

A shipper can choose the outside option: not to ship by railroad. This includes shipping by truck, barge, air or pipeline. The logistics cost of the outside option will depend on the distance to the nearest waterway from the origin and destination, quality of highways connecting the origin and destination points, gas prices, etc. However, as only relative differences in utilities of logistic chains matter, these effects will be captured by market and year fixed effects. I, therefore, use the traditional normalization: the utility shipper j receives from choosing the outside option in market t is given by $U_{i0mt} = \varepsilon_{i0mt}$.

Then the market share of logistic chain k in market m at time t is represented as:

$$s_{kmt} = \int \frac{\exp(x_{kmt}\beta + \alpha_i p_{kmt} + \xi_m + \xi_t + \xi_{kmt})}{1 + \sum_l \exp(x_{lmt}\beta + \alpha_i p_{lmt} + \xi_m + \xi_t + \xi_{lmt})} f(\alpha_i) d\alpha_i \qquad (2.17)$$

2.5.2 Supply

For expositional simplicity, consider a market where two logistic channels are offered, k and h. Channel k is sold by firm j at price $p_k = p_{kj}$ and its market share is s_k, and channel h is a bundle of two complementary products sold by firms l and r (in the context of freight railroad industry, this means that railroads l and r interline). I drop market and time indices for notational simplicity. The composite price of the logistic channel h is $p_h = p_{hl} + p_{hr}$, and its share is s_h. The three firms maximize their profits with respect to price. Market first order conditions will be characterized by

$$\begin{bmatrix} s_k \\ s_h \\ s_h \end{bmatrix} + \begin{bmatrix} \frac{\partial q_k}{\partial p_k} & 0 & 0 \\ 0 & \frac{\partial q_h}{\partial p_h} & 0 \\ 0 & 0 & \frac{\partial q_h}{\partial p_h} \end{bmatrix} \times \begin{bmatrix} p_{kj} - c_{kj} \\ p_{hl} - c_{hl} \\ p_{hr} - c_{hr} \end{bmatrix} = 0 \tag{2.18}$$

or in matrix notation

$$s + \Omega(p - c) = 0 \tag{2.19}$$

This model differs from traditional methods to estimate supply in structural modelling because it has three first order conditions in a market with only two products. This is due to the fact that one of the products is a bundle of two components.

I define marginal costs for product k offered by firm j in market m at time t as a linear function of observable cost factors w_{kjmt}, and a cost shock ω_{kjmt} that is unobserved by the researcher but known to the firms, so that

$$c_{kjmt} = \gamma w_{kjmt} + \omega_{kjmt} \tag{2.20}$$

where γ is a vector of marginal cost parameters to be estimated. The vector w_{kjmt} includes distance, distance squared, a dummy indicating if firm j interlined freight at the origin or termination; railroad, origin and termination state, and year dummies.

One of the limitations of my data is that I only observe the composite price of the interlined movement, not the separate prices charged by each railroad. I estimate the revenue split using the technique proposed by STB.

Freight revenue is divided by the number of 100-mile blocks traveled by each railroad in the route. The origin and termination railroad is apportioned revenue for an additional block, to allow for pick-up and switching expenses.

2.5.3 Identification

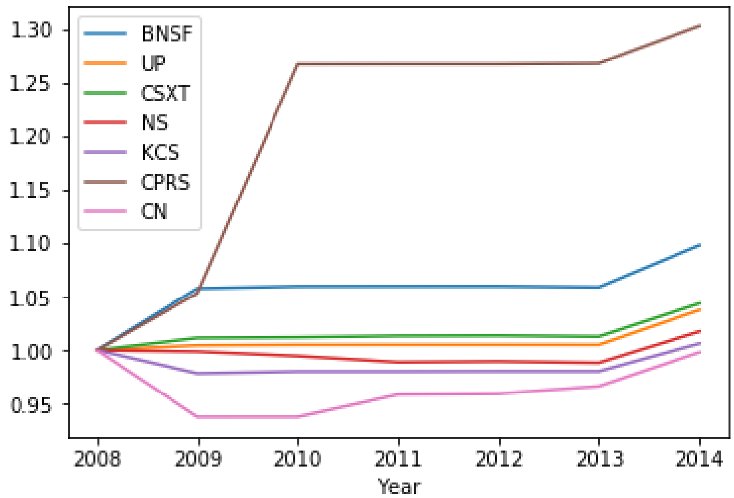
My demand model does not differ significantly from most of those used in modern empirical IO literature, and, therefore, suffers from a traditional threat to the identification. As is the case generally with demand estimation, firms might set their prices based on realizations of unobservable determinants of utility, making price variable endogenous to the choice process. I use two sets of instruments for identifying heterogeneity in consumer preferences.

First, I use access to the railway tracks at origin and destination BEA areas. I use yearly data on miles of tracks owned by a railroad in the origin and termination BEA area from National Transportation Atlas Database, a comprehensive database of North America's railway system. I have access to the data for years 2008-2014 and extrapolate it to prior years. These instrumental variables are a version of the variables used in Ciliberto and Williams (2014). They include average percentage of tracks owned by originating railroad at origin BEA area and terminating railroad at termination BEA area; average percentage of tracks owned as a share of class I railroads; level of potential competition from class I railroads that is defined by the average of percentage of tracks ownership by class I railroads at origin and termination BEA areas net tracks owned by originating railroad at origin BEA area and terminating railroad in termination BEA area; mean number of class I railroads owning tracks in origin and termination BEA area; mean number of railroads owning tracks in origin and termination BEA areas.

In order for our instruments to be valid, they must satisfy two conditions. First, they must be correlated with the price. Access to the railway tracks by the company and its competitors defines the level of potential competition and, therefore, the ability to charge higher prices. The more extensive the firm's network in the area, the easier it is to reach potential clients. Second, the instruments must be exogenous to the structural error. Because railroad companies own tracks, they operate on, adjusting access to tracks would mean building new or retiring old tracks and facilities. Building tracks is a long and expensive process that requires many layers of approvals and extensive planning. Therefore, even if the company decides to adjust access to tracks due to the market-year specific shock, it is unlikely to be realized in the same year, if realized at all. Figure 2.5 shows how track ownership by class I railroads was changing from 2008 to 2014. It is clear that new tracks are being built rarely. CPRS is the only railroad that significantly extended the miles of tracks owned and the majority of the extension happened between 2009 and 2010. Other class I railroads had relatively stable milage of tracks owned from 2009 to 2013.

Second, as additional instruments for prices in the demand equation, I exploit variation in railroad cost shifters, such as staff wages and other operational expenses, over time. The economic assumption is that variation in cost

Figure 2.5: Track Ownership by Class I Railroads



Miles of tracks owned in 2008 are normalized to one.

shifters should be correlated with variation in prices but not with consumers' preferences for unobservable product characteristics. Every class I railroad operating within the United States is required to submit the R-1 Railroad Annual Report to STB. Among other information, the reports provide data about railway freight operating expenses such as salaries and wages, material and supplies, purchased services. I use these data to construct three instrumental variables: expenditures by railroad company on salaries, materials, and purchased services per mile operated in a given year. If in the logistic channel service was provided by interlining multiple railroads, I calculate the average cost per mile among the railroad companies. Unfortunately, the data is not available for non-class I railroads, I, therefore, fill the missing values with the averages.

Finally, to achieve better identification, for some commodity groups, I interact the two sets of the instrumental variable with the distance of haul. For each commodity group, I choose a subset of instruments that provides the best identification of price coefficient. I take into account first stage F-statistics, standard errors and personal judgment when choosing the relevant set of instruments. The description of instrumental variables for each commodity group is provided in the appendix along with F-statistics from the first stage.

Access to tracks at origin and destination BEA areas are also used as instruments in the estimation of supply model. The intuition for the validity of instruments is in line with the above. However, the supply side model is estimated on the logistic chain-firm level, and in the chains with interline, differences between competition at origin and termination points may matter. Therefore, I use track ownership instrumental variables in origin and termination BEA areas instead of averages.

2.5.4 Estimation

I estimate the model using the generalized method of moments (GMM) in the spirit of the seminal work by BLP[12] and the subsequent literature. Given the large data set and complexity of supply-side estimation, I estimate the model by commodity group.

[12]Berry et al. (1995)

Based on the identification arguments from the previous section, chosen instrumental variables, Z_d, are such that at the true demand parameter values θ_d^0, the transitory demand shock $\xi(\theta_d^0)$ are uncorrelated with the instruments. The moment conditions for the demand model can be written as

$$E[Z_d'\xi(\theta_d)] = 0 \tag{2.21}$$

The moment conditions for the supply side can be written as

$$E[Z_s'\omega(\theta_s)] = 0 \tag{2.22}$$

I stack demand and supply moments and estimate the model parameters by minimizing the following objective function

$$\hat{\theta} = \arg\min_{\theta} G(\theta)'\hat{W}^{-1}G(\theta) \tag{2.23}$$

where $G(\theta)$ is set of stacked moments, and $\hat{W}^{-1}$ is a consistent estimate of weighting matrix.

2.5.5 Results

Demand Estimates.

Table 2.6 presents the estimates of the selected demand parameters. I find the price coefficient to be negative, while the coefficient on price interacted with a demographic variable that proxies for enterprise size flips sign based on commodity group. Additionally, the effect of the enterprise size is rather small for most of the commodity groups and not very significant. This can

Table 2.6: Estimates of Selected Demand Parameters

Commodity Group	**Price**	Π
Automotive Products	-66.493***	1.805**
	(9.910)	(0.902)
Chemicals, Fertilizer	-126.870***	2.364**
& Plastics	(36.165)	(1.196)
Coal	-178.856***	-3.875*
	(38.556)	(2.024)
Construction &	-155.061***	-6.788***
Forest Products	(33.328)	(2.427)
Energy Products	-86.368**	4.194**
& Fuels	(36.708)	(1.791)
Food & Beverages	-106.484***	3.442**
	(30.963)	(1.726)
Grains & Feed	-188.754***	2.189***
	(43.177)	(1.032)
Metals & Minerals	-110.928***	-3.217*
	(44.932)	(1.709)
Intermodal	-75.531***	2.059***
	(18.432)	(0.725)

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

be a result of the fact that shippers are not very heterogeneous or numerous. Coal, Construction and Forest Product, and Metals and Minerals have negative coefficients; while other commodity groups have positive coefficients. This indicated that larger firms in the former group are more price sensitive than the smaller firms. Higher price sensitivity may be a result of the ability of larger shippers in the group to negotiate better rates, or contract with truck operators more efficiently. While lower price sensitivity of the larger firms in the latter group may be a result of long-standing contracts between shippers and railroad companies, or inability to ship freight via alternative means of transportation due to the massive amounts of cargo.

Table 2.7: Descriptive Statistics of Estimates of Own Price Elasticity of Demand

Commodity Group	**Mean**	**Median**	**Standard Deviation**
Automotive Products	-4.193	-3.191	4.132
Chemicals, Fertilizer & Plastics	-3.997	-3.466	2.867
Coal	-2.018	-1.699	1.441
Construction & Forest Products	-5.343	-4.810	3.227
Energy Products & Fuels	-2.516	-2.284	1.962
Food & Beverages	-3.259	-2.466	2.842
Grains & Feed	-3.668	-3.510	2.5089
Metals & Minerals	-2.774	-2.291	2.099
Intermodal	-5.166	-3.839	4.463

Table 2.7 presents descriptive statistics of the estimated own price elasticity of demand across markets by commodity group. The median own price elasticity is estimated to be between -1.70 and -4.81. This is in line with the

previous studies that attempted to estimate elasticity of demand in freight railroad industry[13]. The price elasticity is the largest for Construction and Forest Products, Intermodal, Chemical, and Grains and Feed. The differences in elasticities can be attributed to the availability of competition in the markets, both among railroads and other modes of transportation, and substitutability of the modes. For example, the median elasticity estimate for coal is only -1.70 can be because it is hard and expensive to transport coal by truck, and barge transportation is not always available.

Supply Estimates.

Table 2.8 provides estimation results for marginal cost parameters. As expected, I find that the marginal cost of moving one ton of freight is increasing at a decreasing rate with the distance of haul. The result is consistent for all commodity group; however, the rate at which cost increases varies. For example, the coefficient on distance is the largest in Automotive Products commodity group. This most likely because automotive products are hauled on the flat cars most of the time, and the weight per car is relatively small, which translates into higher cost per mile. The average revenue per ton-mile is also the largest for Automotive products commodity group. Interlining freight at the origin or termination has a negative impact on marginal cost. This is due to the costs associated with loading and unloading freight at origin and destination points.

[13]Abdelwahab (1998), Hsing (1994), Rich et al. (2011), Rich et al. (2009)

Table 2.8: Marginal Cost Estimates

Commodity Group	Distance	Distance^2	Junct Or	Junct Tr	Median MC/Mile ($)
Automotive	0.1261***	-0.0358***	-0.0543***	-0.0572***	0.1121
Products	(0.0058)	(0.0033)	(0.0020)	(0.0018)	
Chemicals,	0.0291***	-0.0078***	-0.0130***	-0.0146***	0.0409
Fertilizer & Plastics	(0.0015)	(0.0013)	(0.0003)	(0.0003)	
Coal	0.0135***	-0.0049***	-0.0084***	-0.0091***	0.0192
	(0.0012)	(0.0009)	(0.0002)	(0.0003)	
Construction &	0.0370***	-0.0110***	-0.0146***	-0.0113***	0.0395
Forest Products	(0.0012)	(0.0006)	(0.0004)	(0.0004)	
Energy Products	0.0353***	-0.0152***	-0.0150***	-0.0157***	0.0485
& Fuels	(0.0027)	(0.0025)	(0.0007)	(0.0008)	
Food &	0.0470***	-0.0108***	-0.0206***	-0.0199***	0.0319
Beverages	(0.0016)	(0.0008)	(0.0006)	(0.0006)	
Grains & Feed	0.0321***	-0.0124***	-0.0162***	-0.0154***	0.0276
	(0.0013)	(0.0010)	(0.0004)	(0.0004)	
Metals &	0.0356***	-0.0092***	-0.0111***	-0.0104***	0.0375
Minerals	(0.0007)	(0.0004)	(0.0002)	(0.0002)	
Intermodal	0.0928***	-0.0261***	-0.0525***	-0.0460***	0.0459
	(0.0026)	(0.0010)	(0.0013)	(0.0013)	

** p <0.10, ** p <0.05, *** p <0.01

Note: Marginal cost (dependent variable) is in 1,000, distance in 10,000.

Median of the marginal cost normalized by distance across all markets for a commodity group varies from \$0.112 for Automotive Products to \$0.019 for coal. A Study of competition in the U.S. freight railroad industry conducted on behalf of STB (Eakin et al. (2008)) found that industry average marginal cost per ton-mile was about 1.75 cents in 2006 in the year 2000 dollars. Readjusting for inflation and taking into account that I estimate economic costs, meaning that they also include opportunity costs, my results are not too far away from those found in the study. Bulk goods, such as coal and grain have relatively lower marginal cost as compared to general freight. Intuitively, the cost is lower for bulk commodities, because railroads utilize dedicated unit trains to move grain or coal solely, which reduces operational cost. This is in line with the findings of Ivaldi and Mccullough (2010) that estimate Generalized McFadden cost function for bulk, intermodal and general freight.

2.6 Merger Simulations

In this section, I conduct a counterfactual analysis to measure the welfare effect of mergers in the freight railroad industry. I compare the current state of the market to four counterfactual scenarios. In each of the scenario, I will let one of the firms that operates in the West to coordinate in setting prices in all markets with one of the firms from the East. This is a simple approximation of a merger. I assume that this arrangement will not influence demand in any way other than through the change in prices charged and that it will not result in cost changes. I use estimated marginal costs and re-compute equilibrium price on my data set when full coordination between the two firms is allowed. Table 2.9 provides welfare effects of merger simulations.

Table 2.9: Welfare Effects of Mergers

Merging Firms	Profit Δ of Merging Firms ($M)	Profit Δ of Other Firms ($M)	Profit Δ ($M)	CS Δ ($M)	Welfare Δ ($M)
BNSF, NS	1,383	-1,141	242	862	1,104
BNSF, CSXT	457	-255	203	491	694
UP, NS	752	-508	243	723	967
UP, CSXT	416	-222	194	680	874

Four mergers result in positive welfare change, where both firms' profits and consumer surplus are increased. The merger of BNSF and NS results in the largest welfare change with the increase of over $1 billion dollars. The merger of BNSF and CSXT results in the smallest welfare change of about $700 million. About 80% of welfare change is attributed to the increase in the consumer surplus. While these numbers can look like a small portion of the total industry revenue, they can be substantial to the shippers that are affected the most.

Results of all four counterfactual scenarios have a typical pattern. As a group, merging firms and consumers benefit, and outsider firms loose profit. It is worth noting that while consumers as a group benefit, individual consumers in some markets may suffer due to the merger; in particular, in the markets where merging firms compete. Outsider firms, those that are not part of the merger, loose as a group; however, in some markets outsider firms benefit due to the merger; the result depends on market structure and demand characteristics. This is in line with the discussion in section 2.2.2. Nevertheless, outsiders often lose due to mergers. They lose in the markets where, by merging, complementary firms reduce their pricing externality and become more aggressive competitors to the substitute firm; as well as due to vertical exclusion post-merger.

Table 2.10 provides a breakdown of welfare effects by commodity group. Numbers (1)-(9) in the headers are coded commodity groups. Crosswalk of codes to commodity groups is provided in table 2.11. Most considerable portion of welfare change and consumer surplus change due to mergers of BNSF and NS, and BNSF and CSXT come from coal. While welfare effects of mergers of UP and NS, and UP and CSXT are split among Chemicals, Coal, Metals & Minerals, and Intermodal commodity groups, this indicates that different mergers affect shippers in substantially different ways. The degree of change in consumer surplus is related to the number of markets in which merging parties interline, number of markets in which they compete, and corresponding cost and demand characteristics of the markets. For example, BNSF and CSXT interline in 163 markets in Intermodal commodity group, and they compete in 281[14]; because the number of markets where they compete is relatively high as

[14] Markets here are defined as market-year. Two railroads are defined to compete both when they have parallel routes, and when they are a part of competing logistic chains. For

Table 2.10: Welfare Effects of Mergers by Commodity Group and Number of Markets Served Jointly.

Total Welfare Change as Percentage of Total									
Merging Firms	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
BNSF, NS	1%	0%	65%	0%	4%	4%	-1%	9%	17%
BNSF, CSXT	2%	5%	70%	0%	9%	4%	0%	2%	8%
UP, NS	1%	20%	20%	0%	5%	2%	0%	21%	31%
UP, CSXT	2%	12%	29%	0%	0%	13%	0%	13%	32%
CS Change as Percentage of Total									
Merging Firms	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
BNSF, NS	0%	4%	66%	0%	4%	4%	-2%	7%	16%
BNSF, CSXT	2%	9%	67%	0%	10%	5%	0%	-2%	9%
UP, NS	-7%	23%	25%	0%	4%	2%	0%	19%	33%
UP, CSXT	2%	17%	26%	0%	0%	11%	0%	13%	31%
Number of Markets with Common Interline									
Merging Firms	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
BNSF, NS	35	125	69	5	13	40	3	114	316
BNSF, CSXT	24	138	61	3	15	40	2	44	163
UP, NS	61	269	48	10	38	59	0	151	462
UP, CSXT	51	245	43	6	5	106	0	89	404
Number of Markets where Compete									
Merging Firms	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
BNSF, NS	57	175	45	21	38	62	18	182	371
BNSF, CSXT	21	180	33	13	12	52	1	138	281
UP, NS	127	293	48	17	42	94	19	152	460
UP, CSXT	42	300	16	9	4	82	1	128	359

Note: See commodity group codes in table 2.11.

example, if in a market two logistic chains are offered, one jointly by BNSF and NS, another one jointly by UP and CSXT, then BNSF and CSXT would be considered as competitors.

Table 2.11: Commodity Group Codes

Code	Commodity Group
(1)	Automotive Products
(2)	Chemicals, Fertilizer & Plastic
(3)	Coal
(4)	Construction & Forest Products
(5)	Energy Products & Fuel
(6)	Food & Beverages
(7)	Grains & Feed
(8)	Metals & Minerals
(9)	Intermodal

compared to the markets where they interline, the welfare effects of the merger of this pair for Intermodal commodity group is not large.

2.7 Conclusion

In this chapter, I investigate the welfare implications of mergers in the freight railroad industry in the United States. In the markets where firms sell both substitutes and perfect complements, the welfare effects of a merger is twofold. First, it may be welfare reducing due to the increased price of substitutes. Second, it may be welfare enhancing due to decreased inefficiency from the pricing of complements.

The freight railroad industry is distinct from other modes of freight transport in a way that railroad companies own the tracks they operate on, and the owner of the track is usually the sole operator on the line. There is no single transcontinental railroad company, and if a shipper needs to move freight from the east coast to the west coast, he needs to employ services of at least two different railroad companies. There are two duopolies, one in the West, with BNSF and UP, and one in the East, with NS and CSXT.

I estimate a structural model of demand and supply in the freight railroad industry for nine distinct commodity groups and using the estimated parameters conduct pairwise merger simulations to connect two coasts. I find that all four mergers result in positive welfare changes where both firms and consumers benefit. BNSF and NS merger results in the largest welfare increase. Merging firms and consumers benefit from the mergers as a group, while firms that are outsiders to the mergers lose profits.

Chapter 3

Tacit Collusion with Complements in the Freight Railroad Industry

3.1 Introduction

The standard literature on tacit collusion concentrates on how it influences the pricing of substitutes. However, collusion is also likely to influence the pricing of complements. For example, in static equilibrium, if two local monopolists were selling complementary products, they would charge a higher price than if both products were offered by a single multiproduct monopolist, reducing both the industry profits and the consumer surplus. However, if firms were able to coordinate, they could reach a Pareto improvement by lowering prices to the monopolist level. Therefore, in the markets where firms sell both substitutes and perfect complements, the welfare effect of tacit collusion is twofold. First, it may be welfare reducing due to the increased price of substitutes. Second, it may be welfare enhancing due to decreased inefficiency from the pricing of complements.

I incorporate a model of pricing of complementary products with a model of cooperation when firms meet in multiple markets and analyze this question in the context of the U.S. freight railroad industry. The question is relevant to the industry, because there is no single transcontinental railroad company, and a shipper that needs to move goods from the east coast to the west coast would have to use the services of multiple railroads, and therefore, purchase perfect complements. Freight railroads own the infrastructure they operate on, including tracks, and therefore, most of the time, the owner of the tracks is the sole operator on the line. There are two geographical duopolies, one in the East and one in the West, and a couple of other companies that offer routes in the northern part of the U.S. and Canada, along Mississippi River, and in the South and Mexico. No merger proposal has been submitted to the freight railroad industry regulator since the 2000s. However, some of the railroad industry experts are convinced that the industry will become even more consolidated. Hunter Harrison, a former CEO of Canadian Pacific Railway, stated that the "final round of mergers is not a question of if, but when." Therefore, it is important to understand the welfare implications of this consolidation. It is not the intent of this chapter to provide a merger simulation analysis. Nevertheless, the findings of this chapter can help understand the scope of the competition in the industry, and whether vertical merger to form a transcontinental railroad will increase efficiency by removing the problem of complementary goods pricing. Recent decisions by the Antitrust agencies in the U.S. and the EU highlighted that efficiencies from eliminating the "tragedy of anticommons" and reduced competition should be carefully weighted against each other.

The economic theory of complements or “tragedy of anticommons” dates back to Cournot (1838). Researches have analysed different forms of coordination that can be established to take better account of the interactions between demands for complementary goods. For example, airline codesharing agreements (Brueckner and Whalen (2000), Brueckner (2003), Ito and Lee (2005)), or alliances in supply chains (Stallkamp (2001) discusses alliances formations among auto part suppliers, patent pooling (Shapiro (2001), Lampe and Moser (2010)).

Formal alliances do not need to be established to achieve coordination in setting fares. Firms may be able to tacitly collude if the market conditions are favorable. I use literature on multimarket contact to study how well firms can coordinate both in setting rates for complementary products, and thus reduce inefficiency, and in setting rates for substitutes, and thus reduce competition. The economic literature has shown that when firms face the same competitors in many markets, they may achieve cooperative outcome easier. Bernheim and Whinston (1990) theoretically proved that firms with multimarket contact could be able to sustain a collusive pricing equilibrium under repeated competitions with a lower discount factor. Since Bernheim and Whinston, the effect of multimarket contact on collusive pricing has been investigated in various industries, such as airline [1], cement [2], telecommunications [3], radio [4], and many other[5]. Except for Ciliberto and Williams (2014)

[1] Evans and Kessides (1994), Singal (1996), Miller (2010), Ciliberto and Williams (2014)
[2] Jans and Rosenbaum (1997)
[3] Parker and Röller (1997), Busse (2000)
[4] Waldfogel and Wulf (2006)
[5] Movies: Feinberg (2014); hotels: Fernandez and Marin (1998); retail lumber: Shim et al.

and Shim et al. (2017), most of the research has been conducted as a reduced-form analysis by regressing the level of contact on price. They find that the higher level of multimarket contact is associated with increased prices. Ciliberto and Williams (2014) estimate a flexible model of oligopolistic behavior, where conduct parameters are modeled as a function of multimarket contact. My model is different from Ciliberto and Williams (2014) because it incorporates pricing of perfect complements into the structural model. To the best of my knowledge, this is the first model that shows that the level of multimarket contact not only facilitates collusion in setting prices for substitute goods but also facilitates coordination in pricing complements. This is also a first research that studies the influence of multimarket contact on cooperation in the freight railroad industry.

To guide the structural model, and to test for coordination effects in setting rates, I estimate an analog of a regression from Evans and Kessides (1994), where I regress price on the level of multimarket contact averaged over the firms competing in the market. I find that prices are increasing with the level of contact, which is in line with the hypothesis of "mutual forbearance." In the structural analysis, I extend the model of Ciliberto and Williams (2014) to account for perfect complements. The model includes conduct parameters which capture the degree of cooperation and measure the impact of multimarket contact on collusion. I model conduct parameters as a function of

(2017); pharmaceutical: Coronado et al. (2014); automobile: Leheyda (2008); semiconductor: Chuang et al. (2018); hospitals: Schmitt (2018); health insurance: Lin and McCarthy (2018).

pair-specific multimarket contact, the number of markets in which firms operate simultaneously, and allow conduct to vary for different commodity groups, and when firms sell complements and substitutes. I find that the coefficient on multimarket contact is significant and positive, implying that multimarket contact leads to higher prices of substitutes than those from a competitive Bertrand-Nash equilibrium, but lower prices of complements. Using the parameter estimates, I conduct a counterfactual analysis and present welfare effects of breaking coordination in the pricing of both substitutes and complements, breaking coordination in setting rates for substitutes, but enforcing full coordination in setting rates for complements, and full collusion.

The rest of the chapter is organized as follows. Section 2 provides a short theoretical background on cooperation game in complementary monopoly. Section 3 defines multimarket contact and presents reduced form evidence. Section 4 describes the structural model, identification arguments and estimation results. Section 5 and present counterfactual analyses. Section 6 concludes.

3.2 Theoretical Background

3.2.1 Cooperation Game in Complementary Monopoly

Section 2.2.1 discusses the theoretical background behind the "tragedy of the anticommons" or double marginalization in complementary monopoly. It explains that firms would be better off if they could cooperate and set the monopoly price. This is a classic example of a prisoner's dilemma. If players repeatedly interact over time, according to the "folk theorem," one can support cooperation in infinitely-repeated games with sufficiently high discount factors.

Let's return back to the simple example from section 2.2.1. There are two goods that are perfect complements, i.e. consuming one without another gives zero utility. The demand function for the composite good is

$$Q = Q_1 = Q_2 = A - (P_1 + P_2) \tag{3.1}$$

where P_1 is the price of good 1, and P_2 is the price of good 2. The marginal cost of production of good 1 and 2 is c_1 and c_2 respectively. It has been shown that under Bertrand competition, the profit of each firm is

$$\pi_i^B = \frac{1}{9}(A - c_1 - c_2)^2 \tag{3.2}$$

while in the scenario where firms set a monopoly price and split the profit equally, each would get

$$\pi_i^M = \frac{1}{8}(A - c_1 - c_2)^2 \tag{3.3}$$

Now consider an infinitely repeated cooperation game without uncertainty where on equilibrium path firms set price that results in equal split of monopoly profits.

$$P_i^M = \frac{A + 3c_i - c_j}{4} \tag{3.4}$$

If one of the firms deviates, cooperation breaks by reversion to Bertrand pricing forever. Firm i's best response function to the price of firm j is

$$P_i(P_j) = \frac{A + c_i - P_j}{2} \tag{3.5}$$

Therefore, if firm i were to deviate when firm j charges P_j^M, firm i's price would be

$$P_i^D = \frac{3A + 5c_i - 3c_j}{8} \tag{3.6}$$

This would result in demand that is equal to

$$Q^D = \frac{3}{8}(A - c_i - c_j) \tag{3.7}$$

And firm i's deviation profit would be

$$\pi_i^D = \left(\frac{3}{8}\right)^2 (A - c_i - c_j)^2 \tag{3.8}$$

The above strategy can be sustained as an outcome of a subgame perfect Nash equilibria if and only if one stage deviation is not profitable, or sum of discounted profits from cooperating exceed profits from deviating

$$\pi_i^D + \frac{\delta}{1-\delta}\pi_i^B \leq \frac{1}{1-\delta}\pi_i^M \tag{3.9}$$

This inequality holds when $\delta \geq 0.53$. Here δ is a discount factor that measures how "patient" the firm is. Therefore, with high enough values of a discount factor, it is possible to achieve cooperation in the infinitely repeated game of complementary monopoly.

3.2.2 Multimarket Contact and Cooperation Game

Both empirical and theoretical research in the past has been concerned that the interaction of firms across markets can enhance coordination. Bernheim and Whinston (1990) in their seminal paper on multimarket contact examine its effect on the degree of cooperation that firms can sustain in a setting of repeated competition across multiple markets. They find that when markets and firms are identical, equilibrium outcome does not change when firms treat markets separately (act like single-product firms in each market) or make pricing decision considering all markets together as a multimarket firm. Therefore, multimarket contact does not enhance collusion. They call this "an irrelevance result." Nevertheless, they find that in the industries with differing markets or firms, multimarket contact may have an impact on the ability of firms to sustain collusive pricing by relaxing the incentive constraint. Slack in the incentive constraints from one market can be transferred to the other.

Their theoretical findings can be easily extended to the economy with perfect complements. Therefore, it may be the case that multimarket contact has a real effect on the pricing of complements and may be able to reduce inefficiency from the "tragedy of the anticommons." The question of whether there is the inefficiency and what the effect of the multimarket contact is in mitigating this inefficiency should be resolved through empirical research.

3.3 Reduced Form Analysis

3.3.1 Multimarket Contact

I define a contact between firms k and h as operating in a market simultaneously at time period t. This includes both competing and interlining freight. For now, let's break multimarket contact into two separate variables, $mmc\_il_{kh}^t$ and $mmc\_c_{kh}^t$. $mmc\_il_{kh}^t$ is the number of markets where two railroads, k and h, interline freight

$$mmc\_il_{kh}^{t} = \sum_{m} D\_IL_{kh}^{mt} \tag{3.10}$$

where $D\_IL_{kh}^{mt}$ is equal to one if firms k and h interline in market m at time t. $mmc\_c_{kh}^{t}$ is the number of markets where railroads k and h compete

$$mmc\_c_{kh}^{t} = \sum_{m} D\_C_{kh}^{mt} \tag{3.11}$$

where $D\_C_{kh}^{mt}$ is equal to one if firms k and h actively compete in market m at time t. For each year I construct a matrix of these pair-specific variables. Table 3.1 shows the matrix, mmc_il_{kh} for 2003, and table 3.2 shows the matrix, mmc_c_{kh} for 2003.

Table 3.1: Number of Markets with a Common Interline in 2003

	BNSF	UP	CSXT	NS	KCS	CPRS	CN
BNSF		71	64	87	32	7	23
UP	71		94	108	23	25	41
CSXT	64	94		54	6	11	33
NS	87	108	54		19	14	22
KCS	32	23	6	19		0	15
CPRS	7	25	11	14	0		6
CN	23	41	33	22	15	6	

The highest level of interline contact is among NS and UP, CSXT and UP, and BNSF and NS. It comes with no surprise given the rail network structure. Interlining between railroads serving west, UP and BNSF, and railroads serving east, NS and CSXT, allows freight to move via rail from

Table 3.2: Number of Markets where Firms Compete in 2003

	BNSF	UP	CSXT	NS	KCS	CPRS	CN
BNSF		508	84	110	54	60	56
UP	508		102	135	69	27	84
CSXT	84	102		464	16	30	67
NS	110	135	464		34	29	78
KCS	54	69	16	34		2	23
CPRS	60	27	30	29	2		22
CN	56	84	67	78	23	22	

coast to coast. The highest level of competition multimarket contact by far is for BNSF and UP, and CSXT and NS, which is again unsurprising, as there are two geographic duopolies one in the west and one in the east.

I define total multimarket contact, mmc_{kh}^t, as the sum of $mmc\_il_{kh}^t$ and $mmc\_c_{kh}^t$. For each year, I then use mmc_{kh}^t to calculate market-year specific average of multimarket contact for interlining firms or those selling complements, $AvgMMC\_Compl_{mt}$ and for competing firms or those selling substitutes, $AvgMMC\_Subst_{mt}$.

$$AvgMMC\_Compl_{mt} = \frac{1}{N_{mt}} \sum_{k=1}^{F} \sum_{h=1,h\neq k}^{F} D\_IL_{kh}^{mt} \cdot mmc_{kh}^t/100 \tag{3.12}$$

$$AvgMMC\_Subst_{mt} = \frac{1}{N_{mt}^{il}} \sum_{k=1}^{F} \sum_{h=1,h\neq k}^{F} D\_C_{kh}^{mt} \cdot mmc_{kh}^t/100 \tag{3.13}$$

where F is the total number of railroads, $N_{mt}^{il} = \sum_{k=1}^{F} \sum_{h=1,h\neq k}^{F} D\_IL_{kh}^{mt}$ is the number of pairs of interlining firms in market m at time t, $N_{mt}^{c} = \sum_{k=1}^{F} \sum_{h=1,h\neq k}^{F} D\_C_{kh}^{mt}$ is the number of pairs of competing firms in market m

at time t. Thus, $AvgMMC\_Compl_{mt}$ and $AvgMMC\_Subst_{mt}$ are equal to the average mmc^t_{kh} across the firms actively competing and interlining in the market m respectively, divided by 100.

Table 3.3 provides summary statistics for $AvgMMC$ variables for the markets where the contact is non-zero, i.e. in case of $AvgMMC\_Compl_{mt}$, summary statistics was calculated over the markets where there is an interline, while summary statistics for $AvgMMC\_Subst_{mt}$ was calculated in non-monopolistic markets.

Table 3.3: Summary Statistic for AvgMMC Variables

	AvgMMC Compl	AvgMMC Subs
Mean	1.121	2.736
Standard Deviation	1.306	1.797
Median	0.720	2.379
Minimum	0.010	0.010
Maximum	5.870	5.870

Note: summary statistics is for the markets where AvgMMC is non-zero.

3.3.2 Endogeneity of MMC and Instrumental Variables

Ciliberto and Williams (2014) discuss that average multimarket contact is likely to be endogenous to prices because unobservable shocks that influence price are also likely to affect entry and exit decisions of a firm that define multimarket contact. I use yearly data on miles of tracks owned by a railroad in the origin and termination BEA area from National Transportation Atlas Database, a comprehensive database of North America's railway system, to construct instrumental variables that are used both in reduced-form and structural analysis. These instrumental variables are a version of the variables used in Ciliberto and Williams (2014) and are identical to the instrumental variables discussed in section 2.5.3. The intuition comes from the fact that a railroad company needs access to rail tracks to serve a market, and it is unlikely to adjust the mileage of tracks in the origin or termination BEA area in response to unexpected changes in demand and cost. Because railroad companies own tracks, they operate on, adjusting access to tracks would mean building new or retiring old tracks and facilities. Building tracks is a long and expensive process that requires many layers of approvals and extensive planning. Therefore, even if the company decides to adjust access to tracks due to the market-year specific shock, it is unlikely to be realized in the same year, if realized at all.

3.3.3 Multimarket Contact in the Freight Railroad Industry

In this section, I conduct a series of reduced form analysis to investigate whether multimarket contact influences prices in the freight railroad industry. First, I test if multimarket contact facilitates cooperation in setting prices of complementary goods and helps reduce inefficiency. I run a regression analogous to (2.14) and additionally control for the level of average multimarket contact between interlining firms.

Table 3.4 provides estimation results for OLS and IV regressions. The

Table 3.4: Effect of Average Multimarket Contact on Interline Pricing

	OLS	IV
Constant	2.028***	1.991***
	(0.091)	(0.116)
ln(Miles)	-0.437***	-0.440***
	(0.007)	(0.009)
ln(Tons)	-0.074***	-0.074***
	(0.004)	(0.004)
ln(Tons/Car)	-0.452***	-0.452***
	(0.021)	(0.021)
Private Car	-0.121***	-0.120***
	(0.010)	(0.010)
IL	0.199***	0.309***
	(0.016)	(0.105)
AvgMMC Compl	-0.009	-0.050**
	(0.006)	(0.024)

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

coefficient on IL is positive and statistically significant in both cases. The coefficient on average multimarket contact is negative in both cases and statistically significant at 5% significance level in the instrumental variable estimation. This means that higher contact between interlining firms is associated with a lower price. To understand the economic significance of the estimated coefficient I follow Evans and Kessides (1994) and multiply it by the change in $AvgMMC\ Compl$ when moving from the market with an interline with the twenty-fifth percentile in contact to a market with the seventy-fifth percentile, which is 1.25. Such a change in multimarket contact corresponds to a change of 6.3% in revenue per ton-mile in IV regression. Therefore, the total effect of interline on railroad rates in monopoly markets is estimated to vary between 30.8%, in the markets with the lowest contact, and almost 0%, in the markets with the highest contact.

The exercises above supports the theory of complementary monopoly pricing. It provides evidence that prices are on average higher in the markets with complementary goods than in integrated monopoly markets, where a single firm offers two complements forming a composite good. Moreover, the magnitude of the price increase varies with the firms selling complements. This variation may arise from the difference in market conditions the firms operate in or from the ability to cooperate while setting rates. Estimating structural model will help us understand this phenomenon better.

Next, I replicate the work of Evans and Kessides (1994) in the setting of the freight railroad industry. Evans and Kessides test the hypothesis that multimarket contact facilitates collusion by regressing logarithm of price on average multimarket contact. The regression specification is as follows

$$\ln RTM_{jmt} = \beta X_{jmt} + \alpha AvgMMC\_Subs_{mt} + \varepsilon_{jmt} \tag{3.14}$$

where j indexes product, m markets, and t year. The dependent variable and control variables, X_{jmt}, are as in (2.14) plus an interline dummy IL_{mt}. As before, I include time and commodity group fixed effects, origin and termination BEA area dummies and origin and termination railroad dummies. The main variable of interest is $AvgMMC\_Subs_{mt}$ and I expects its coefficient to be positive. In this specification IL_{mt} is equal to 1 if a product with an interline is offered in the market. Microeconomic theory suggests that in differentiated product markets if one of the products offered is a composite of complementary goods sold by different firms, then prices for all products in the market will be higher than if an integrated firm was offering the complementary goods. Therefore, I expect the coefficient on IL_{mt} variable to be positive. This is an additional test for the existence of the tragedy of anticommons.

Table 3.5: Effect of Multimarket Contact on Revenue per Ton-Mile

	(1) OLS	(2) IV
Constant	2.452***	2.298***
	(0.045)	(0.051)
ln(Miles)	-0.434***	-0.421***
	(0.003)	(0.004)
ln(Tons)	-0.078***	-0.091***
	(0.003)	(0.002)
ln(Tons/Car)	-0.514***	-0.491***
	(0.012)	(0.012)
Private Car	-0.146***	-0.146***
	(0.005)	(0.006)
IL	0.119***	0.101***
	(0.004)	(0.010)
AvgMMC Subs	0.004***	0.191***
	(0.001)	(0.036)

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Column (1) of table 3.5 estimates the model using ordinary least squares estimation procedure. Column (2) of table 3.5 presents results from instrumental variable regression. As discussed above, $AvgMMC\_Subs_{mt}$ variable is likely to be endogenous because it is determined by the entry and exit decisions of the firm. Instrumental variables are defined and discussed in section 3.3.2. Estimated coefficients on control variables have expected sign, and their magnitude is consistent with previous research on rate setting in the freight railroad industry. The coefficient on IL variable is positive and statistically significant. It indicates that prices in the markets with at least one interline among transportation options offered are about 10% higher than in the markets without interlines, ceteris paribus. The coefficient on average multimarket contact among competing firms is positive and statistically significant and is equal to 0.191. Moving from an oligopolistic market with the twenty-fifth percentile in contact to a market with the seventy-fifth percentile changes multimarket contact by 3.42 and would increase revenue per ton-mile by 65.3%.

3.4 Structural Model

3.4.1 Model

In this section, I provide a structural model of cooperation when firms meet in multiple markets. I use a differentiated product model to estimate the demand for railroad freight transportation. The demand side of the model is identical to the one discussed in section 2.5.1. In the modeling supply side, I follow Ciliberto and Williams (2014) and extend their model to account for perfect complements. They use the degree of pair-specific multimarket contact between carriers as a "market environment" shifter. The idea is that higher levels of multimarket contact between firms may facilitate cooperation in setting rates. They define conduct parameter, the degree of coordination between carriers l and r, as a function of the level of multimarket contact, $f(mmc_{lr})$. If conduct parameter is equal to zero, they conclude that the firms do not cooperate. If the conduct parameter is equal to one, then firms can sustain a fully collusive outcome. Conduct parameter between zero and one would indicate that firms are coordinating up to some extent, but not fully. In the markets where firms with high conduct parameter sell substitutes, the prices are expected to be higher than in Bertrand-Nash outcome, and therefore collusion is welfare reducing. However, in the markets where firms sell perfect complements, the high level of cooperation will translate into lower prices, and higher welfare, as the inefficiency of "tragedy of anticommons" will be reduced.

For expositional simplicity, consider a market where two logistic channels are offered, k and h. Channel k is sold by firm j at price $p_k = p_{kj}$ and its market share is s_k, and channel h is a bundle of two complementary products sold by firms l and r (in the context of freight railroad industry, this means that railroads l and r interline). I drop market and time indices for notational simplicity. The composite price of the logistic channel h is $p_h = p_{hl} + p_{hr}$, and its share is s_h. The three firms solve profit maximization problem with coordination. Market first order conditions will be characterized by

$$\begin{bmatrix} s_k \\ s_h \\ s_h \end{bmatrix} + \begin{bmatrix} \frac{\partial q_k}{\partial p_k} & \theta_{jl}\frac{\partial q_h}{\partial p_k} & \theta_{jr}\frac{\partial q_h}{\partial p_k} \\ \theta_{lj}\frac{\partial q_k}{\partial p_h} & \frac{\partial q_h}{\partial p_h} & \theta_{lr}\frac{\partial q_h}{\partial p_h} \\ \theta_{rj}\frac{\partial q_k}{\partial p_h} & \theta_{rl}\frac{\partial q_h}{\partial p_h} & \frac{\partial q_h}{\partial p_h} \end{bmatrix} \times \begin{bmatrix} p_{kj} - c_{kj} \\ p_{hl} - c_{hl} \\ p_{hr} - c_{hr} \end{bmatrix} = 0 \tag{3.15}$$

or in matrix notation

$$s + \Omega(\theta)(p - c) = 0 \tag{3.16}$$

The first order condition of firm l can be rewritten as

$$s_h + \frac{\partial q_h}{\partial p_h}\left[(p_{hl} - c_{hl}) + \theta_{lr}(p_{hr} - c_{hr})\right] + \theta_{lj}\frac{\partial q_h}{\partial p_h} = 0 \tag{3.17}$$

As in Ciliberto and Williams (2014) the first-order conditions now have additional cooperative terms as compared to Bertrand first order condition. These terms depend on the size of the conduct parameter, degree to which firms coordinate in setting rates, and the derivatives of shares with respect to the prices. If the products that two firms are offering are substitutes, then the degree to which cooperation increases prices depends on the level of substitution of the two products. The closer the substitutes are, the higher the fares will be compared to Bertrand-Nash outcome. If the two products are perfect complements, then the higher the own price elasticity is, the lower the price will be. Recall, that the "tragedy of anicommons" in the context of pricing of perfect complements arises because firms do not take into account each others margins. In FOC (3.17) θ_{lr} denotes the extent to which firm l incorporates margin of firm r into its pricing decision.

I model the conduct parameter as

$$f(mmc_{lr}^t) = \frac{\exp(\phi_1^h + \phi_2^h mmc_{lr}^t)}{1 + \exp(\phi_1^h + \phi_2^h mmc_{lr}^t)} \tag{3.18}$$

where h indicates if the products are substitutes or complements. The reason for estimating conduct parameters separately for substitutes and complements is that apart from multimarket contact, firms may be able to utilize other legal instruments to achieve Pareto-improvement in setting fares on interlined freight. I expect ϕ_2 to be positive, which would indicate that multimarket contact facilitates cooperation. This functional form bounds conduct parameters between zero and one and allows for imperfect collusion.

In principle, conduct parameters may vary across markets, as pointed out by Bernheim and Whinston (1990) and Fan et al. (2018). However, estimating a fully flexible conduct matrix would require a prohibitive number of instrumental variables. To keep the estimation tractable, the need to restrict the structure of the conduct parameter in an economically reasonable way arises. I estimate a vector of parameters ϕ separately for each commodity group, allowing the level of cooperation to vary across commodities.

I define marginal costs as a linear function of observable cost factors w_{kjmt}, and a cost shock ω_{kjmt} identical to the section 2.5.2, so that

$$c_{kjmt} = \gamma w_{kjmt} + \omega_{kjmt} \tag{3.19}$$

where γ is a vector of marginal cost parameters to be estimated. The vector w_{kjmt} includes distance, distance squared, a dummy indicating if firm j interlined freight at the origin or termination; railroad, origin and termination state, and year dummies.

3.4.2 Identification

Identification of demand-side parameters is discussed in the section 2.5.3. The primary difficulty of the supply side estimation is to separately identify the level of industry conduct from unobserved marginal cost shocks. Pair-specific multimarket contact is likely to be endogenous, as discussed in section 3.3.2. Supply-side first-order optimality conditions are conducive in understanding the type of variation needed to identify conduct parameters. The main determinants of the prices are cross-price and own-price elasticities and pair-specific multimarket contact. Thus, to identify the degree of coordination in setting fares, one must have instruments that explain both the substitutability of carriers' service and which carriers serve the market. Track ownership instrumental variables do well in identifying these relationships, because they capture the identity of the firms that can potentially serve the market, and the level of potential competition in the market, i.e., if service can be provided by other railroads and how easily, this identifies substitutability.

3.4.3 Estimation

I estimate the model using the generalized method of moments (GMM) similar to the estimation procedure in the section 2.5.4. Supply side adds vector ϕ to the outer loop routine of BLP estimation. Combining equations (3.16) and (3.19), one can rewrite cost shock as a function of conduct parameters, $\omega_{kjmt} = \omega(\phi^0)$. The moment conditions for the supply side can be written as

$$E[Z_s'\omega(\phi^0)] = 0 \tag{3.20}$$

I stack demand and supply moments and estimate the model parameters by minimizing the following objective function

$$\hat{\theta} = \arg\min_{\theta} G(\theta)'\hat{W}^{-1}G(\theta) \tag{3.21}$$

where $G(\theta)$ is set of stacked moments, and $\hat{W}^{-1}$ is a consistent estimate of weighting matrix.

3.4.4 Results

Demand-side estimation results and results of the estimation of marginal cost parameters are in line with the results in section 2.5.5. They can be found in the appendix.

Table 3.6 provides estimates of conduct parameter coefficients. Estimates vary by commodity group and when firms sell substitutes or complements. The common trend is that multimarket contact is positively correlated with the conduct. Figures 3.1 and 3.2 plot these relationships. We can see that conduct parameter for complements if non-zero even for the firms that meet in few markets. This is in line with the economic literature that firms may be able to internally achieve Pareto improvement and reduce the inefficiency form pricing complements. The fact that conduct parameters differ across commodity groups is also in line with the theory. Bernheim and Whinston (1990) find that if goods are differentiated and firms meet in multiple markets when firms cannot sustain a fully collusive outcome, they may be able to gain by shifting market power between markets. The level of collusion that firms can sustain depends on the cost structure and market conditions.

Table 3.6: Conduct Parameter Estimates

	Conduct Substitutes		Conduct Complements	
Commodity Group	Const	MMC	Const	MMC
Automotive Products	-5.928**	0.030**	-0.913**	0.006**
	(2.995)	(0.015)	(0.431)	(0.003)
Chemicals, Fertilizer & Plastics	-7.154**	0.017**	-1.682**	0.008*
	(3.473)	(0.008)	(0.818)	(0.005)
Coal	-21.248***	0.059***	-8.005**	0.060**
	(5.172)	(0.020)	(3.848)	(0.030)
Construction & Forest Products	-4.889***	0.019***	-1.765***	0.016**
	(1.856)	(0.006)	(0.735)	(0.008)
Energy Products & Fuels	-7.542*	0.051**	-1.989***	0.010***
	(4.436)	(0.026)	(0.664)	(0.003)
Food & Beverages	-6.875***	0.020**	-1.005**	0.005***
	(2.050)	(0.010)	(0.510)	(0.002)
Grains & Feed	-2.874**	0.022**	-0.991**	0.012*
	(1.402)	(0.011)	(0.481)	(0.007)
Metals & Minerals	-4.878***	0.027**	-2.086**	0.030**
	(1.606)	(0.014)	(0.998)	(0.015)
Intermodal	-4.763***	0.017***	-1.567***	0.006***
	(1.360)	(0.005)	(0.522)	(0.002)

* p <0.10, ** p <0.05, *** p <0.01

Figure 3.1: Conduct Parameters as Functions of Multimarket Contact: Substitutes

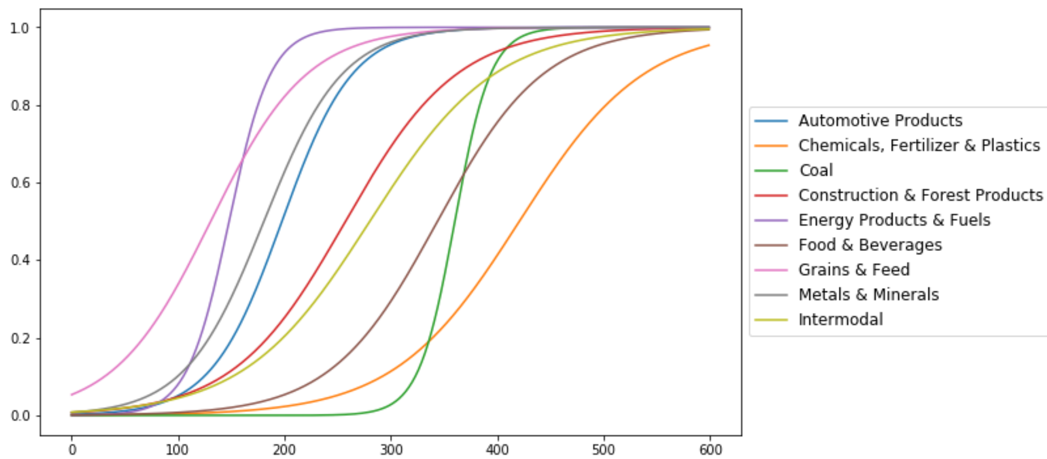
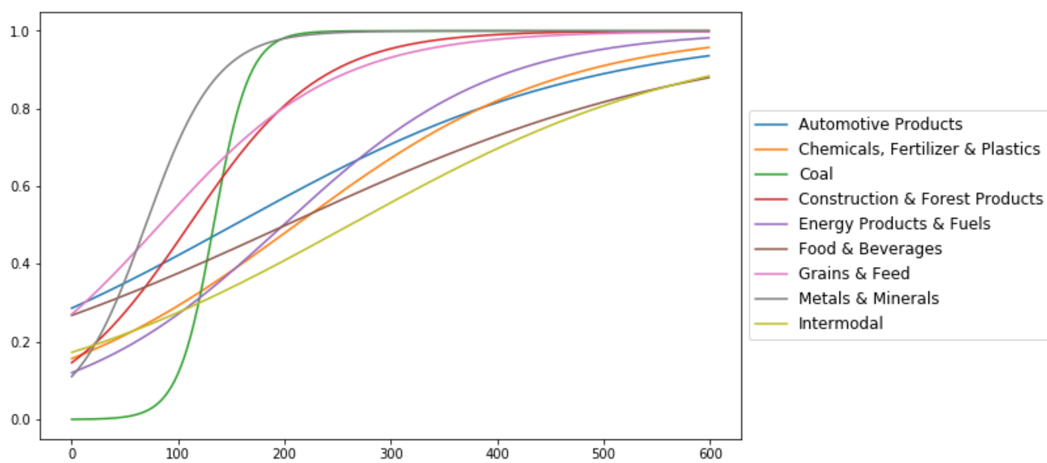


Figure 3.2: Conduct Parameters as Functions of Multimarket Contact: Complements



Tables 3.7 and 3.8 provide a one-to-one mapping from the level of multimarket contact to the level of cooperation that railroad companies could sustain while setting rates for substitutes and complements in 2003 in Metals

& Minerals commodity groups markets. BNSF - UP and CSXT - NS pairs had the highest level of multimarket contact, they met in 579 and 518 markets respectively. The conduct parameter for substitute goods for both pairs is close to one, indicating that BNSF and UP, and CSXT and NS collude in the markets where they sell substitutes. The results suggest that firms operating in the two geographic duopolies are able to sustain close to monopoly price in Metals & Minerals commodity groups markets, and as can be seen from figure 3.1, this results holds for most of the commodity groups. Now consider CSXT and BNSF, in 2003 they met in 148 markets. Table 3.7 shows that conduct parameter for substitutes is equal to 0.29, indicating that CSXT and BNSF were able to sustain a low level of cooperation. Conduct parameters for other pairs go as low as 0.008, which implies that they do not coordinate in setting fares for substitutes.

Table 3.7: Conduct Parameters for Class I Railroads in 2003: Substitutes Metals & Minerals Commodity Group

	BNSF	UP	CSXT	NS	KCS	CPRS	CN
BNSF		1.0000	0.2928	0.6085	0.0720	0.0433	0.0604
UP	1.0000		0.6020	0.8433	0.0836	0.0301	0.1820
CSXT	0.2928	0.6020		0.9999	0.0136	0.0219	0.1017
NS	0.6085	0.8433	0.9999		0.0309	0.0214	0.1017
KCS	0.0720	0.0836	0.0136	0.0309		0.0080	0.0208
CPRS	0.0433	0.0301	0.0219	0.0214	0.0080		0.0160
CN	0.0604	0.1820	0.1017	0.1017	0.0208	0.0160	

Table 3.8: Conduct Parameters for Class I Railroads in 2003: Complements Metals & Minerals Commodity Group

	BNSF	UP	CSXT	NS	KCS	CPRS	CN
BNSF		1.0000	0.9133	0.9786	0.6210	0.4735	0.5705
UP	1.0000		0.9780	0.9945	0.6624	0.3715	0.8408
CSXT	0.9133	0.9780		1.0000	0.1937	0.2919	0.7138
NS	0.9786	0.9945	1.0000		0.3785	0.2858	0.7138
KCS	0.6210	0.6624	0.1937	0.3785		0.1165	0.2797
CPRS	0.4735	0.3715	0.2919	0.2858	0.1165		0.2234
CN	0.5705	0.8408	0.7138	0.7138	0.2797	0.2234	

Interestingly, firms can sustain coordination in setting fares for complements easier than for substitutes. In Metals & Minerals Commodity Group in 2003, all pairs composed from four largest railroads (BNSF, UP, CSXT, and NS) were able to sustain near-perfect coordination in setting rates for complementary goods.

3.5 Counterfactual Analysis

In this section, I conduct a counterfactual analysis to measure the welfare effect of coordination in setting rates in the freight railroad industry. I compare the current state of the market to two counterfactual scenarios. First, that the regulator breaks coordination entirely, both in setting rates for substitute goods and complements. I implement this by setting all conduct parameters to be equal to zero. Second, I evaluate the welfare effects of full coordination. I simulate an industry with a single multiproduct monopolist by setting all conduct parameters to one.

Table 3.9: Counterfactual Results: Breaking Collusion (in $B)

	Δ Profit	Δ CS	Δ Welfare
Automotive Products	-3.383	3.690	0.307
Chemicals, Fertilizer & Plastics	-2.593	2.925	0.332
Coal	-13.016	19.694	6.678
Construction & Forest Products	-0.896	0.935	0.040
Energy Products & Fuels	-0.732	0.587	-0.145
Food & Beverages	-1.655	1.974	0.319
Grains & Feed	-2.958	3.059	0.100
Metals & Minerals	-2.133	2.158	0.025
Intermodal	-12.699	16.369	3.669
Total	-40.065	51.391	11.326

The table 3.9 shows the results of the first counterfactual conducted on the full data set. I find that the regulation which prohibits coordination in setting rates both for complements and substitutes increases customer surplus while decreasing company profit. This result is robust across commodity groups. The positive sign on the change of consumer surplus indicates that effects of coordination on consumer surplus from pricing substitutes outweigh the effect from pricing complements. Moreover, in all commodity groups but Energy Products & Fuels, the welfare change is positive, meaning that consumers gain more than firms lose from breaking collusion.

Table 3.10: Counterfactual Results: Full Collusion (in $B)

	Δ Profit	Δ CS	Δ Welfare
Automotive Products	1.467	-1.816	-0.348
Chemicals, Fertilizer & Plastics	1.919	-2.221	-0.302
Coal	10.528	-10.189	0.339
Construction & Forest Products	0.083	-0.124	-0.041
Energy Products & Fuels	0.651	-0.388	0.263
Food & Beverages	0.594	-0.907	-0.313
Grains & Feed	1.028	-0.966	0.062
Metals & Minerals	2.003	-2.034	-0.031
Intermodal	5.281	-5.427	-0.146
Total	23.555	-24.072	-0.517

The table 3.10 provides results of the second counterfactual. Allowing full coordination in setting rates has an opposing effect. This policy intervention increases industry profits and decreases customer surplus. However, the magnitude of the change is lower than in the previous counterfactual. This is because companies in two geographical duopolies are already able to sustain close to full collusion.

3.6 Conclusion

In this chapter, I investigate the impact of multimarket contact on coordination in the freight railroad industry and measure its welfare effects on consumers and firms. In the markets where firms sell both substitutes and perfect complements, the welfare effect of tacit collusion is twofold. First, it may be welfare reducing due to the increased price of substitutes. Second, it may be welfare enhancing due to decreased inefficiency from the pricing of complements. I extend the framework of Ciliberto and Williams (2014) to account for pricing of perfect complements and assess the degree of collusion on reducing the inefficiency caused by the "tragedy of anticommons." To the best of my knowledge, this is the first paper that shows that the level of multimarket contact not only facilitates collusion in setting prices for substitute goods but also facilitates coordination in pricing complements.

I find that multimarket contact leads to higher prices of substitutes than those from a competitive Bertrand-Nash equilibrium, but lower prices of complements. I also find that the lower level of multimarket contact is needed to achieve coordination when setting rates for complements, than substitutes. Using the parameter estimates, I conduct a counterfactual analysis and present welfare effects of breaking coordination in the pricing of both substitutes and complements and full collusion. The results suggest that breaking collusion is welfare enhancing while allowing for full coordination has a small but negative effect. Unfortunately, due to the model limitations, I am not able to conduct merger simulations. The conduct parameter is an equilibrium object and thus will change after a merger.

My analysis is limited in several ways. First, as pointed out by Bernheim and Whinston (1990) and Fan et al. (2018), and in line with Corts (1999), conduct parameters may vary across markets. Future research may estimate a more flexible supply model to asses the level of coordination. The model of Fan et al. (2018) allows for estimation of firm markups with a flexible supply model and can be extended to account for perfect complements. The limitation of their model is that the solution has not yet been derived for the random coefficient demand. Second, I only observe the composite price of the interlined movement, not the separate prices charged by each railroad. I estimate the revenue split using the technique proposed by STB. This technique may not account for the market power of the railroads and therefore produce biased results.

Appendices

Appendix A

STB Carload Waybill Sample

I use unmasked confidential STB Carload Waybill Sample (CWS) for the years 2003 through 2014 as the primary data source. The sample is a collection of railroad waybill records submitted to the STB by rail carriers that terminate 4,500 or more revenue carloads annually. It is roughly a 3% stratified sample of shipment level observations which is then expanded to represent 100% of all rail traffic. The sample includes information about the origin and destination of the shipment, distance of haul, goods transported, their weight, railroads participating in the movement, revenue collected, etc. A small percentage of interlined traffic in CWS was rebilled: reported as two separate shipments. Data indicates which waybills were rebilled and if rebill happened at origin or termination. I attempt to correct for rebilling using the procedure described below. First, I link rebilled waybills that had identical waybill number, had a common interline point, and originated within 10 days. Next, I link waybills that had the same car number, equal weight and the number of carloads, hauled the same commodity, had common interline and originated within 10 days. Because CWS is a sample, not every waybill will be represented in the data. Therefore, the above procedure is not able to link all the rebilled waybills. To further correct for rebilling, I create matching of waybills that were rebilled at origin and termination with a common interline point. If the matching is one-to-one, I link the waybills. If it is not one-to-one, I use information from Freight Analysis Framework (FAF) to derive tonnage of freight moved between origin and destination point by rail and create a matching of rebilled waybills that supports the tonnage from FAF.

Appendix B

Demand-side Instrumental Variables

I use two sets of instrumental variables to estimate demand in the structural model. First, I use access to the railway tracks at origin and destination BEA areas. I use yearly data on miles of tracks owned by a railroad in the origin and termination BEA area from National Transportation Atlas Database, a comprehensive database of North America's railway system. I have access to the data for years 2008-2014 and extrapolate it to prior years.

- % Tracks Mean - the average percentage of tracks owned by originating railroad at origin BEA out of all tracks in the area and terminating railroad at termination BEA area.

- % Tracks CI Mean - the average of percentage of tracks ownership by class I railroads at origin and termination BEA areas net tracks owned by originating railroad at origin BEA area and terminating railroad in termination BEA area.

- % of CI Mean - the average percentage of tracks owned as a share of class I railroads.

- N I mean - mean number of class I railroads owning tracks in origin and termination BEA area.

- N mean - mean number of railroads owning tracks in origin and termination BEA areas.

Second, as additional instruments for prices in the demand equation, I exploit variation in railroad cost shifters, such as staff wages and other operational expenses, over time.

- Salaries_mile - expenditures by railroad company on salaries per mile operated

- Material_mile - expenditures by railroad company on materials per mile operated

- PurchServ_mile - expenditures by railroad company on purchased services per mile operated

If in the logistic channel service was provided by interlining multiple railroads, I calculate the average cost per mile among the railroad companies. Unfortunately, the data is not available for non-class I railroads, I, therefore, fill the missing values with the averages.

Finally, for some commodity groups to achieve better identification, I interact the two sets of the instrumental variable with the distance of haul. For each commodity group, I choose a subset of instruments that provides the best identification of price coefficient see table B.1.

Table B.1: Demand-side Instrumental Variables by Commodity Group

Commodity Group	Instrumental Variables	First-stage F-statistic
Automotive Products	Salaries_mile, Material_mile, % Tracks Mean, % Tracks CI Mean, % of CI Mean, N I mean, N mean	132.57
Chemicals, Fertilizer & Plastics	Salaries_mile, Material_mile, PurchServ_mile, % Tracks Mean, N I mean, N mean	25.66
Coal	Salaries_mile, Material_mile, PurchServ_mile, % Tracks Mean, % Tracks CI Mean, N I mean, N mean	117.63
Construction & Forest Products	Salaries_mile, Material_mile, PurchServ_mile, % Tracks Mean, % Tracks CI Mean, % of CI Mean, N I mean, N mean	71.61
Energy Products & Fuels	Salaries_mile, Material_mile, % Tracks Mean, % Tracks CI Mean, % of CI Mean, N I mean, N mean	44.78
Food & Beverages	Salaries_mile, Material_mile, PurchServ_mile, % Tracks Mean, % Tracks CI Mean, % of CI Mean, N I mean, N mean	38.93
Grains & Feed	Salaries_mile, Material_mile, % Tracks CI Mean x miles, N I mean x miles, N mean x miles	41.48
Metals & Minerals	PurchServ_mile, % Tracks Mean, % of CI Mean	17.34
Intermodal	PurchServ_mile, % Tracks CI Mean, % of CI Mean	23.26

Appendix C

Chapter 2 Demand Parameter Estimates

Table C.1: Estimates of Demand Parameters from Chapter 2

Commodity Group	Constant	Junction	D/RD	Distance
Automotive Products	2.361	-0.349	-0.632	0.005
	(0.882)	(0.381)	(0.407)	(0.001)
Chemicals, Fertilizer & Plastics	1.769	-0.276	-2.201	0.004
	(0.645)	(0.345)	(0.308)	(0.001)
Coal	1.314	-0.431	-0.462	0.003
	(0.419)	(0.124)	(0.164)	(0.001)
Construction & Forest Products	-1.442	0.435	-1.347	0.005
	(0.462)	(0.367)	(0.215)	(0.001)
Energy Products & Fuels	-0.805	0.047	-0.615	0.003
	(0.754)	(0.393)	(0.356)	(0.001)
Food & Beverages	1.148	-0.271	-3.854	0.005
	(0.756)	(0.276)	(0.660)	(0.001)
Grains & Feed	2.085	-0.259	-2.485	0.009
	(0.831)	(0.235)	(0.543)	(0.002)
Metals & Minerals	-1.090	-0.039	-1.096	0.005
	(0.287)	(0.403)	(0.148)	(0.002)
Intermodal	-0.799	0.188	-3.115	0.004
	(0.482)	(0.368)	(0.455)	(0.001)

D/RD is the ratio of haul distance to the shortest road distance.

Appendix D

Chapter 3 Parameter Estimates

D.1 Demand Estimates

Table D.1: Estimates of Price Coefficients from Chapter 3

Commodity Group	**Price**	Π
Automotive Products	-84.304	2.990
	(13.192)	(1.539)
Chemicals, Fertilizer	-145.076	1.674
& Plastics	(43.836)	(0.889)
Coal	-238.933	0.764
	(55.112)	(0.519)
Construction &	-188.125	-8.653
Forest Products	(43.669)	(3.093)
Energy Products	-86.892	3.842
& Fuels	(37.300)	(1.723)
Food & Beverages	-123.564	3.342
	(37.725)	(1.709)
Grains & Feed	-171.214	1.901
	(42.298)	(0.896)
Metals & Minerals	-176.953	1.443
	(75.976)	(1.030)
Intermodal	-89.785	3.273
	(23.006)	(1.221)

D.2 Supply Estimates

Table D.2: Marginal Cost Estimates

Commodity Group	Distance	Distance^2	Junct Or	Junct Tr	Median MC/Mile ($)
Automotive Products	0.0924	-0.0291	-0.0448	-0.0572	0.0938
	(0.0043)	(0.0027)	(0.0021)	(0.0017)	
Chemicals, Fertilizer & Plastics	0.0258	-0.0071	-0.0126	-0.0128	0.0349
	(0.0014)	(0.0013)	(0.0004)	(0.0004)	
Coal	0.0106	-0.0043	-0.0070	-0.0082	0.0176
	(0.0010)	(0.0009)	(0.0003)	(0.0004)	
Construction & Forest Products	0.0290	-0.0099	-0.0120	-0.0124	0.0350
	(0.0009)	(0.0005)	(0.0003)	(0.0005)	
Energy Products & Fuels	0.0316	-0.0124	-0.0156	-0.0140	0.0381
	(0.0024)	(0.0020)	(0.0007)	(0.0007)	
Food & Beverages	0.0415	-0.0086	-0.0176	-0.0139	0.0286
	(0.0014)	(0.0006)	(0.0005)	(0.0004)	
Grains & Feed	0.0264	-0.0091	-0.0144	-0.0152	0.0240
	(0.0011)	(0.0007)	(0.0003)	(0.0004)	
Metals & Minerals	0.0278	-0.0076	-0.0077	-0.0093	0.0318
	(0.0005)	(0.0003)	(0.0001)	(0.0002)	
Intermodal	0.0754	-0.0244	-0.0531	-0.0292	0.0396
	(0.0021)	(0.0009)	(0.0013)	(0.0008)	

Note: Marginal cost (dependent variable) is in 1,000, distance in 10,000.

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